Upper Truckee River

Meiss Allotment Aquatic Habitat Trend Analysis

Time series photos of aquatic habitat condition in Big Meadow

UDSA FOREST SERVICE LAKE TAHOE BASIN MANAGEMENT UNIT

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Executive Summary

This report presents an analysis of Stream Condition Inventory (SCI) data on two aquatic habitat monitoring reaches located within the Meiss Grazing Allotment. The SCI protocol was used to track changes in habitat condition over time and to evaluate "total rest" as a management strategy. The first monitoring reach is located on the Upper Truckee River in Meiss Meadow; the second is located on Big Meadow Creek (an Upper Truckee tributary) in the Big Meadow watershed.

Both watersheds are glaciated with stair-stepped topography and meadows forming on shallow sloping treads. Data indicates that the Meiss site is more susceptible to heavy sediment inputs and lateral channel shifting from rare large floods, whereas Big Meadow tends to have a less flashy flood response and large scale stream and meadow changes occur less frequently. Understanding these innate characteristics, resource managers can better understand forces that contribute to time of recovery as a result of rest.

Cattle and Sheep grazing in the area began in the mid-19th century. Evidence suggests that intense grazing and surface water patterns in both meadows were manipulated to optimize livestock forage. The cumulative impact of grazing, surface water management and flooding triggered incision and consequently disconnected both stream channels from the floodplain, more so in Meiss downstream of the Pacific Crest Trail crossing. Grazing impacts in the allotment were recognized in the 1950s and the Forest Service began modifying management practices with grazing adjustments continuing through the 1990's. The allotment was vacated in fall 2001 because the State of California water quality fecal coliform standard could not be met.

SCI data collection began in 1995; nine aquatic habitat attributes were measured in this effort. Measurements were repeated at both sites in 2001, at Big Meadow in 2007, and again at both sites in 2013. Positive trends in eight of the nine attributes indicate improved aquatic habitat function in monitoring areas. The data indicates that channels have narrowed and there are more pools with a much greater percentage of pool area. There is also more instream shade, a greater percentage of stable banks, fewer riffle fines, and coarser riffles overall. Some of these metrics, such as number of pools and pool area recovered rapidly, even while some cattle were still on the land. Others showed a slower but steady positive response through 2013 after the cattle were completely removed.

Rest from cattle grazing has allowed both meadows to recover and stabilize. Although full recovery has not been achieved after 12 years, it does appear that total rest from cattle grazing is a promising management strategy for aquatic habitat recovery. Time of recovery however, will likely depend on natural setting, flood routine, recovery from historic land management, as well as degree of rest.

Introduction

Livestock grazing in the Sierra Nevada has been shown to contribute to degraded aquatic riparian habitats (Kattelmann and Embury, 1996) and cold water fish such as Golden Trout (Knapp and Mathews, 1996). Many areas in the Western US have a 100 to 200 year grazing history, with extensive impacts prior to the Taylor Grazing Reform Act of 1934. Since the act was approved modified grazing strategies have been implemented in the Sierra with some benefit; however data still indicates that aquatic habitat conditions in many areas throughout the Western US remain in a degraded state. In fact, data continues to suggest that full habitat recovery from grazing may require total rest (Belsky et al., 1999). In the Hart National Antelope Refuge in Oregon, a recent study showed it took 23 years of total rest from cattle grazing to restore riparian vegetation and channel form (Batchelor and Ripple, 2015)

Given the current drought condition in California along with the Forest Service's goal to deliver clean water from its forests and grasslands, water quality protection has also become a top management priority. In the Lake Tahoe Basin, water quality standards are quite stringent due to its status as an Outstanding Natural Resource Water (Murphy et al., 2001). Consequently, large-scale grazing in the Tahoe Basin no longer occurs, including the 11,275 acre Meiss Allotment. In 2001, this allotment was vacated because it could not meet State of California fecal coliform standards.

This study looks at two monitoring reaches (Meiss Meadow and Big Meadow) within the Meiss Allotment in the headwaters of the Upper Truckee River **(FIGURE 1)**. The data collected provides a unique opportunity to evaluate aquatic habitat condition after a 12-year period of total rest from cattle grazing. The primary monitoring tool was USFS Region 5 Stream Condition Inventory or SCI (Frazier et al., 2005). Initial measurements on nine aquatic habitat attributes were taken in 1995 and 2001 using the SCI while the areas were still being grazed. Post grazing SCI was repeated in Big Meadow in 2007 and at both reaches in 2013.

This report is organized in three parts. The first section provides information on setting and background related to stream and meadow function, early grazing history and surface water management practices, along with current management strategy. The second section presents the SCI monitoring plan, along with the results of data collected between 1995 and 2013. The final section provides a thoughtful discussion on the utility of the multi-metric SCI protocol, and its ability to qualify aquatic habitat improvements, as well as a short discussion on climate change.

Study results indicate that 12 years of total rest from cattle grazing has improved aquatic habitat form that inferred improved function at both sites; however total recovery has not yet been achieved. Overall, the SCI results do indicate that total rest from livestock grazing is a promising strategy for achieving aquatic habitat recovery and meadow resiliency.

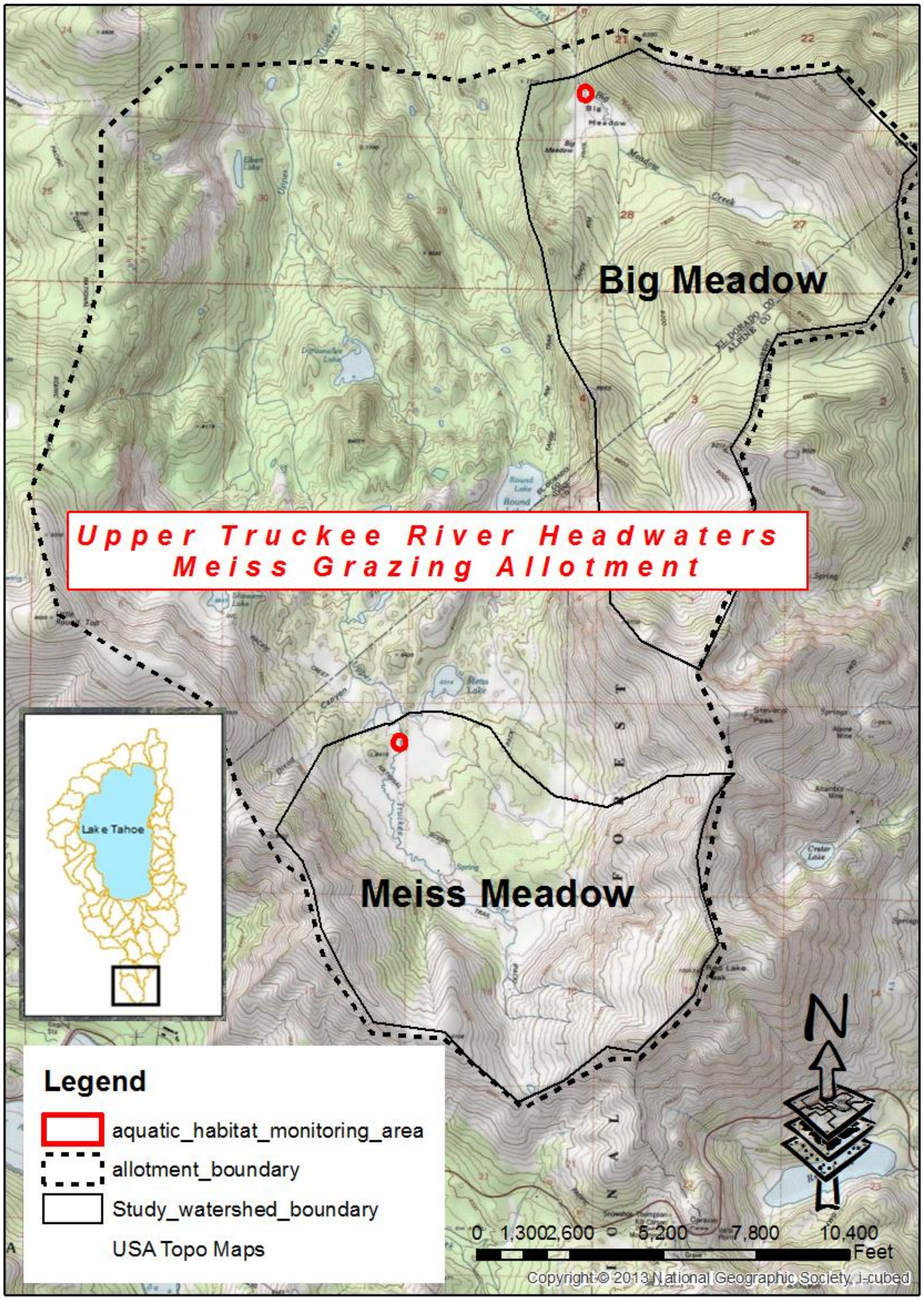

Figure 1 - The Meiss Grazing Allotment and Monitoring Reach locations. Inset map shows the location of the grazing allotment relative to Lake Tahoe CA.

SECTION 1.

Natural Setting

Having a strong understanding of the natural setting and its associated controls and/or influences upon landform is useful to resource professionals in helping to manage expectations for recovery as a result of rest. Specifically, it can help define what might be reasonable to expect in terms of functional stream channel width to depth ratios, or even to better understand the potential conditions or forces that may contribute to recovery and/or degradation of form and function over time. The information presented below will be used in that context and is presented to account for the major similarities and differences in the two monitoring reaches studied. This information will also help to inform the adaptive management process as these meadow systems continue to rest and recover.

The Meiss and Big Meadow watersheds are located in the headwaters of the Upper Truckee River and are glaciated with a characteristic stair-stepped topography. On some of the shallow-sloping steps, meadows and their streams have evolved since the end of the last glacial. Rocks underlying the slopes surrounding Meiss are composed of ancient volcanic deposits classified as Miocene age volcanic rocks that were transported via water (USGS, 2005) i.e. a cool volcanic mudflow. Deposition in cooler environment translates into less bond strength of the rock, making it more readily erodible when compared to the crystalline granite or metamorphic rocks of the Tahoe Basin. The rocks underlying the slopes in the Big Meadow watershed are mostly granite with some Miocene volcanic rock up in the southwestern corner of the watershed. The difference in bedrock composition between the two watersheds suggests that the hillslopes of the Meiss watershed are naturally more erodible, implying that more sediment gets to that meadow quicker which has implications for stream form, type, and function during flood events.

Additional watershed characteristics for comparison are presented in the table below; these characteristics influence local stream form, type, and function at each site.

Watershed Attributes	Big Meadow	Meiss Meadows
Watershed Area (mi^2)	4	2.5
Bedrock Geology	Volcanic / Granitic	Volcanic
Adjacent Forest Setting	Montane (mixed conifer)	Sub-Alpine
% Forest Cover	44	19
Mean Basin Elevation	8330	8853
Monitoring Reach Elevation	7524	8324
Monitoring Reach Length	1148 ft. (350 meters)	3280 ft. (1000 meters)
Mean Annual Precipitation	51.6	53.7
Precipitation type / Runoff	Snow /Snowmelt	Snow/Snowmelt
Bank full discharge (estimated)	30	25

Watershed Characteristics (downloaded from USGS Stream-Stats program)

Both Meiss and Big meadow watersheds are somewhat similar in size, elevation, and precipitation regime, producing similarly sized annual floods as shown by bank full discharge estimates for the monitoring areas in Table 1. Observations of annual floods in both meadows (Oehrli, 1993 -1998 unpublished data) indicate relatively mild spring runoff hydrology, riffle-to-riffle bed load sediment movement, point bar scuplting, and fine sediment deposition common along the channel-meadow margin where the stream accesses its floodplain. These annual floods maintain well-formed single thread meandering channels, a form expected to occur in this geographic environment when the watershed size is greater than roughly 1mi^2 (Wood, 1975).

The two watersheds do behave differently as flood size increases; differences in percent of and proximity to erodible hillslopes and amount of forest cover are primary determinants for sediment transport. These controls influence the timing and volume of coarse and fine sediment transported from the hillslopes to the meadow-channel systems during larger floods.

In general, the Meiss system is steep and tends to be flashy which means the channel receives heavier sediment inputs on a more frequent basis than does the Big Meadow system. The combination of steep, bare, erosive slopes in closer proximity to the meadow encourage water to concentrate and produce sharp peak flows during fall and winter rain, or rain-on-snow flood events. The Meiss monitoring reach also has two valley constrictions partitioning the meadow into three separate areas **(FIGURE 2**). The zones around the in-valley constrictions can be very dynamic due to the hydraulics at the valley constrictions; this is where sediment accumulation, abrupt channel shifting, and recovery of channel form is expected to occur naturally.

In contrast, the Big Meadow system **(FIGURE 3)** does not have inter-meadow valley constrictions and is therefore unlikely to experience heavy sediment inputs with abrupt changes to channel position. There is a valley constriction below the meadow that may temper sediment inputs further. In addition, there is more forest cover and the hillslopes (except for the uppermost southern tip of the watershed) are not as steep as in Meiss, implying flood peaks and sediment response would not typically be as sharp. Although LIDAR mapping evidence indicates sediment-heavy floods have occurred in the past, their reoccurrence is less common. The LIDAR image of Big Meadow in **FIGURE 4** reveals features that look like deposits from larger floods and a relic channel west of the modern stream. The shift from the relic to the modern channel may have been abrupt due the absence of meander migration scars, which tend to be present when lateral migration is gradual. Today’s channel appears to have settled into a younger (yellow shaded) tongue-shaped flood deposit and has been in nearly the same location since 1940.

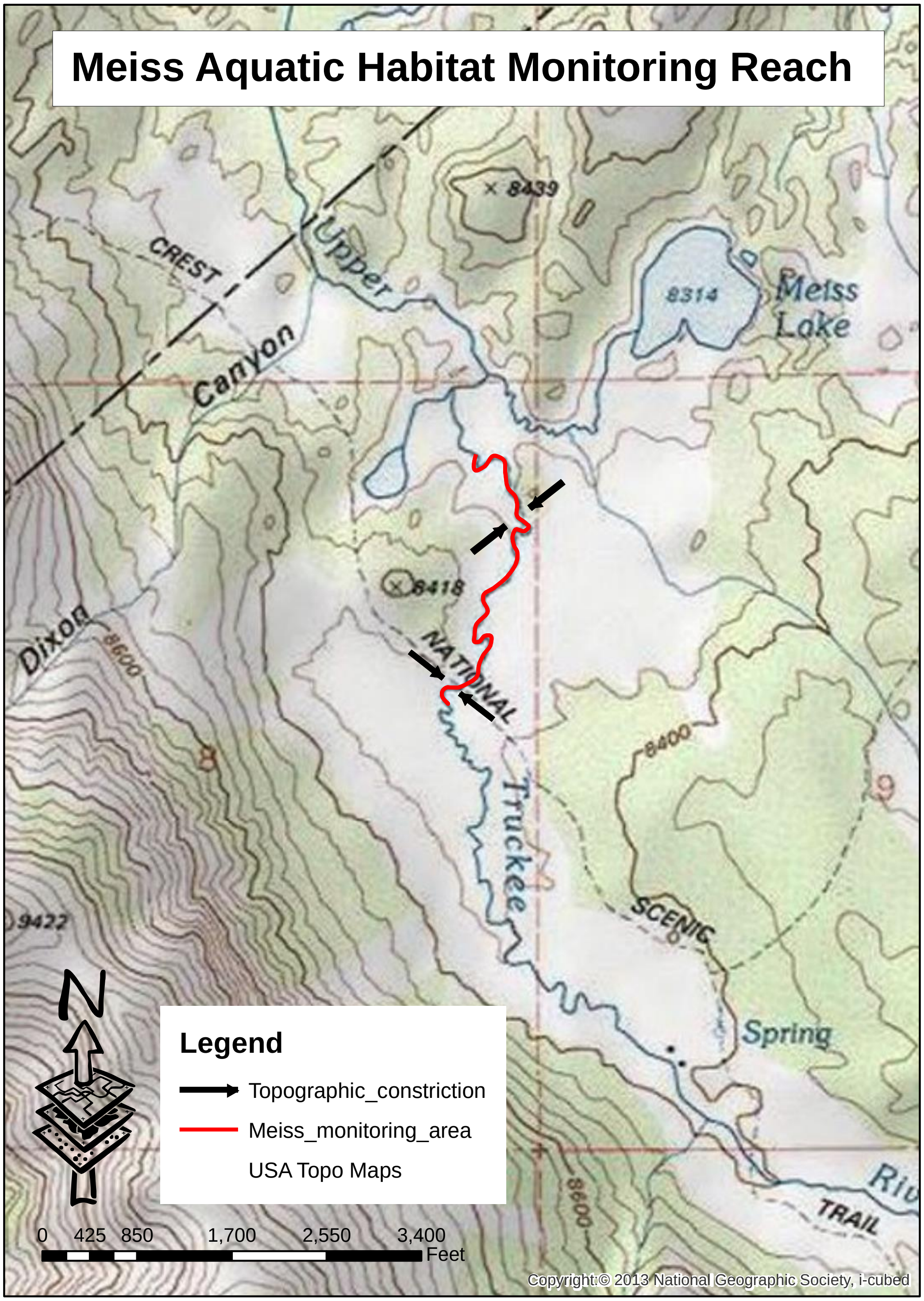

FIGURE 2 - Meiss Meadow Monitoring Reach. Black arrows are shown to indicate two inter-meadow topographic constrictions. The Pacific Crest Trail Crossing (PCT) is located on the upper inter-meadow constriction. The channel may have been placed in the lower constriction to control surface flow and meadow wetness to support livestock.

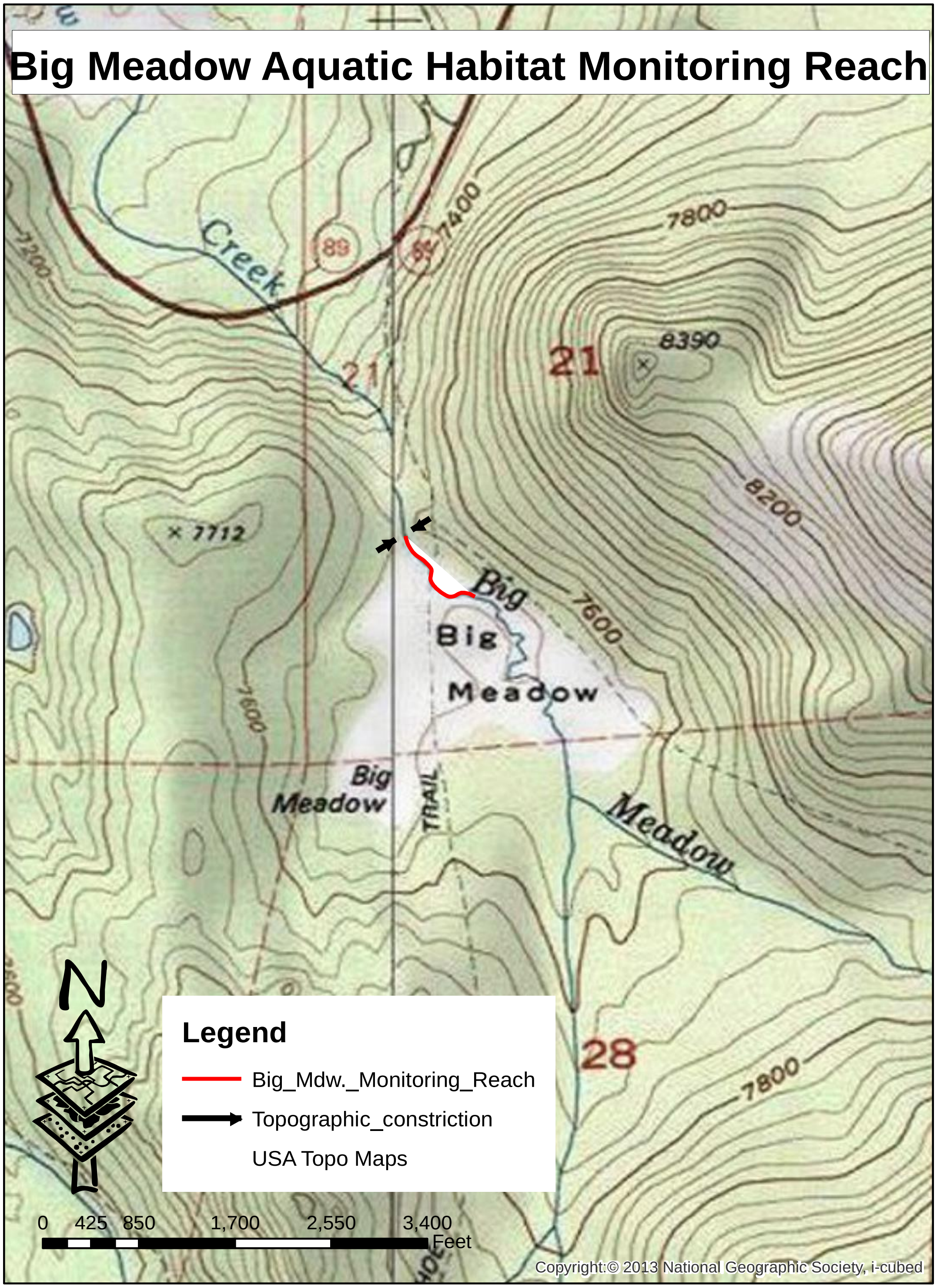

FIGURE 3 - Big Meadow Aquatic Habitat Monitoring Reach. Black arrows are shown to indicate a topographic constriction at the downstream end of the meadow.

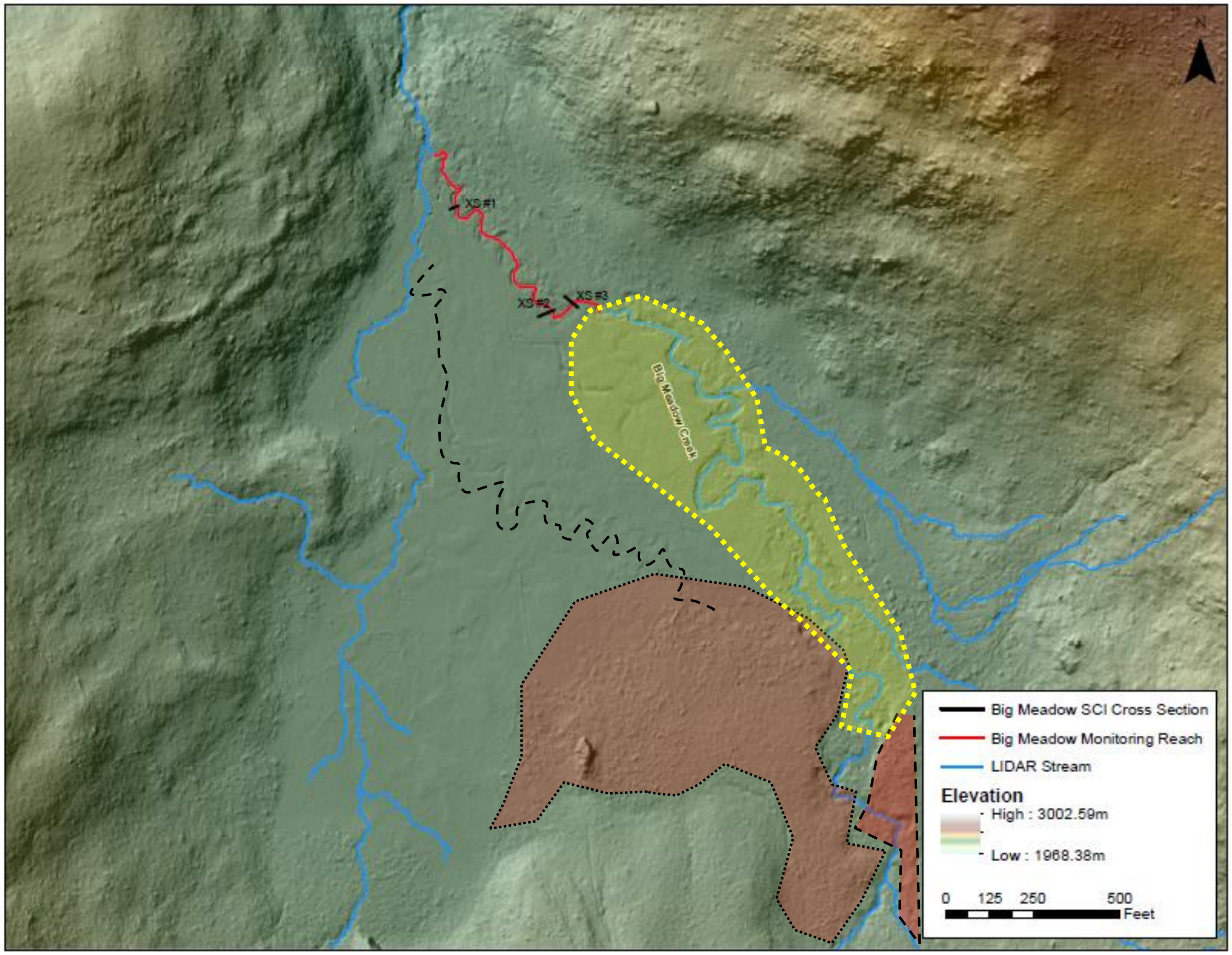

FIGURE 4 - Big Meadow extreme flood deposits (red and yellow shaded polygons), relic channel (dashed line), and channels (blue line). Aerial photos indicate the existing channel has remained in the approximately the same location over the last 73 years.

Studying the process of recovery related to form and function is never an exact science. However understanding the nature and the character of surrounding landforms, as well as the availability or type of building materials and forces in the watershed that shape depositional environments, will greatly improve resource manager's understanding of recovery. The factors controlling natural channel function can also be useful in helping to interpret certain data differences seen through physical data collection from the SCI protocol presented in a later section of this document. Information presented in the next chapter also provides a look at natural setting influenced by historic grazing and surface water management practices.

Early Grazing History and Surface Water Management

Both natural forces and manmade influences can affect form and function upon a landscape. In the Meiss and Big Meadow watersheds, there is a long history of landscape alteration which accompanied sheep and cattle grazing operations in the mid-19th century. Evidence suggests that intense grazing and surface water patterns in both meadows were modified to optimize livestock forage. The cumulative impact of grazing, surface water management and flooding triggered incision and consequently disconnected both stream channels from the floodplain and to greater degree in Meiss downstream of the PCT. Grazing impacts throughout the allotment were recognized in the 1950s and the Forest Service began modifying grazing practices with adjustments continuing through the 1990's.

Meiss Meadows

The Meiss Meadow grazing history dates back to 1868 (USFS, 1999). Louis Meiss ran livestock in the area until 1918. Animal numbers are not known for this time but were likely the highest concentration of grazing animals present on the landscape due to high demand for beef during the Silver Mining boom in Western Nevada. The Meiss family continued running operations until 1937, where 1200 sheep, 250 cows, and 15 horses grazed within Meiss Meadow and the surrounding area. These numbers are still relatively high when compared with modern day animal numbers in the 1990's.

After 1937, the Schneider family acquired the Meiss allotment and sheep grazing was discontinued and cattle grazing continued through 2001. Meadow resource impacts were recognized in the 1950's by Forest Service staff which resulted in a reduction of animal numbers (USFS, 1993); animal numbers after 1966 were reduced still further. From 1966 to 1981, 200 cows with calves were on the allotment from mid-July to mid-October. From 1982 thru 1991 about 125 cows with calves were present and 100 cows with calves from 1992 thru 2000. There were also two years (1996 and 98) when no grazing took place due to a heavy winter snow pack that led to excessively wet summer soil conditions. In the final year of 2001, use was limited to 50 cows with calves in the allotment.

In addition to impacts such as widening of stream channels, and compacted soil surfaces typical of heavy grazing (Belsky et. al, 1999), these systems were subject to a short but intense storm event on December 9-12 1937 (USGS, 1939). The USGS estimates that about 8 inches of liquid (a combination of rain and melting snow) ran off this 12.4 mi^2 drainage area and triggered a cumulative peak flow into Caples Lake of approximately 2200 CFS at 1100 on December 11th, producing a runoff-drainage area ratio of 177 CFS/ mi^2. Assuming Meiss (an adjacent watershed) also had a runoff-drainage area ratio around 177 CFS/ mi^2, it could be classified as a rare large flood. The 1940 aerial photo also provides evidence that the flood flushed significant sediment into the stream. The aerial **(FIGURE 4)** shows the primary flow path had extensive braiding and longitudinal bar formation as sediments splayed out across bends in the channel. The evidence also suggests the channel avulsed at the lower end of the meadow creating a fan shaped sediment deposit.

While effects from the flood were significant, man-made channel modifications were likely a major contributor to channel incision as well. Topographic evidence strongly suggests that significant channelization to regain control of surface flow to reduce meadow wetness in order to support a longer grazing season. This assumption is supported by images shown in FIGURE 5 where a portion of the stream channel appears suspiciously straightened. Specifically, the stream channel follows the topographic contour whereas a natural channel would tend to align more perpendicular. A network of stream channel diversions and ditches also appears to be a common feature on the landscape. The end result, whatever the historic sequence of events might have been, is the main flow path in Meiss Meadow eroded its bed and banks disconnecting itself from the floodplain, a condition that still persists today below the PCT.

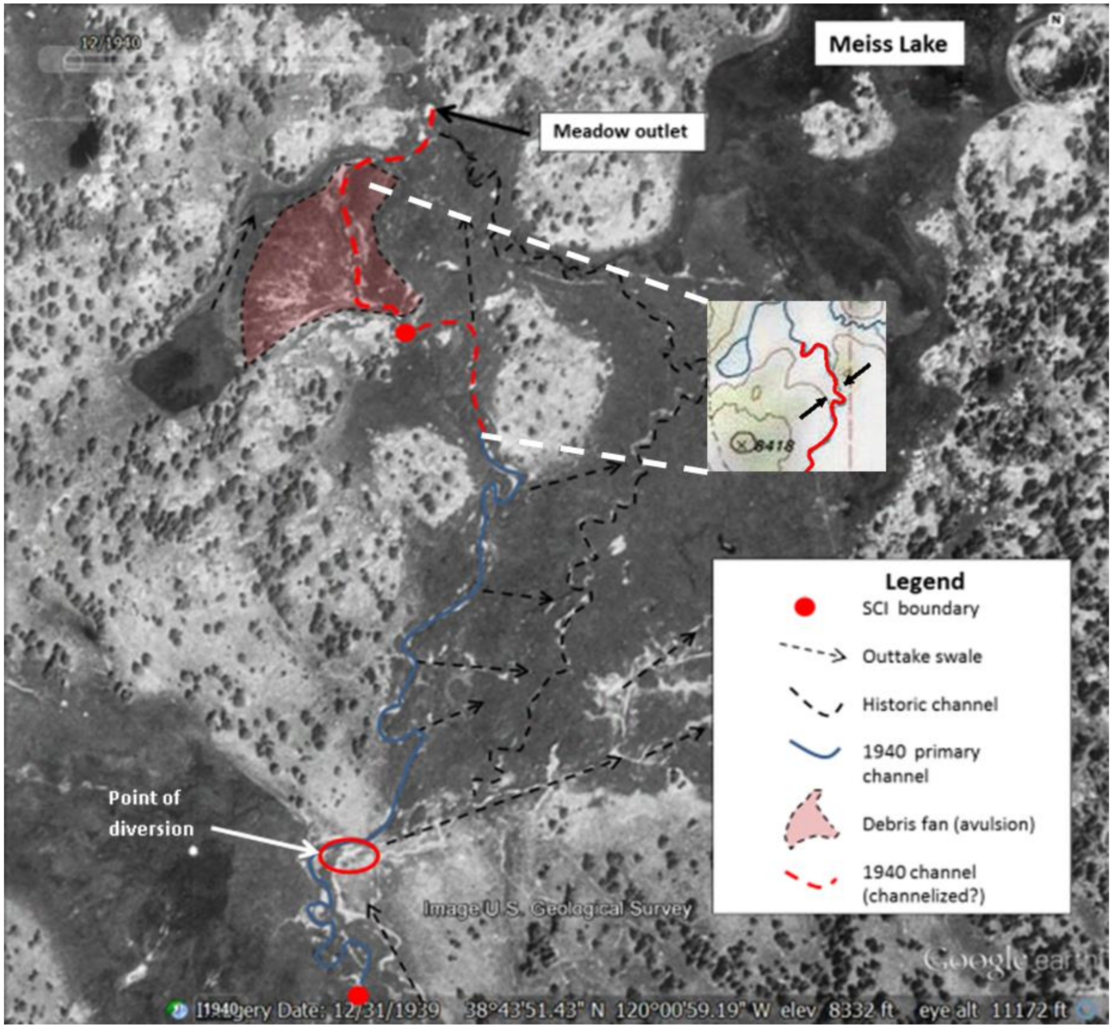

Figure 5 – 1940 Aerial photo of Meiss Meadows and Meiss monitoring reach. Modern USGS topographic data (inset) shows how the channel follows contour and then cuts across the valley.

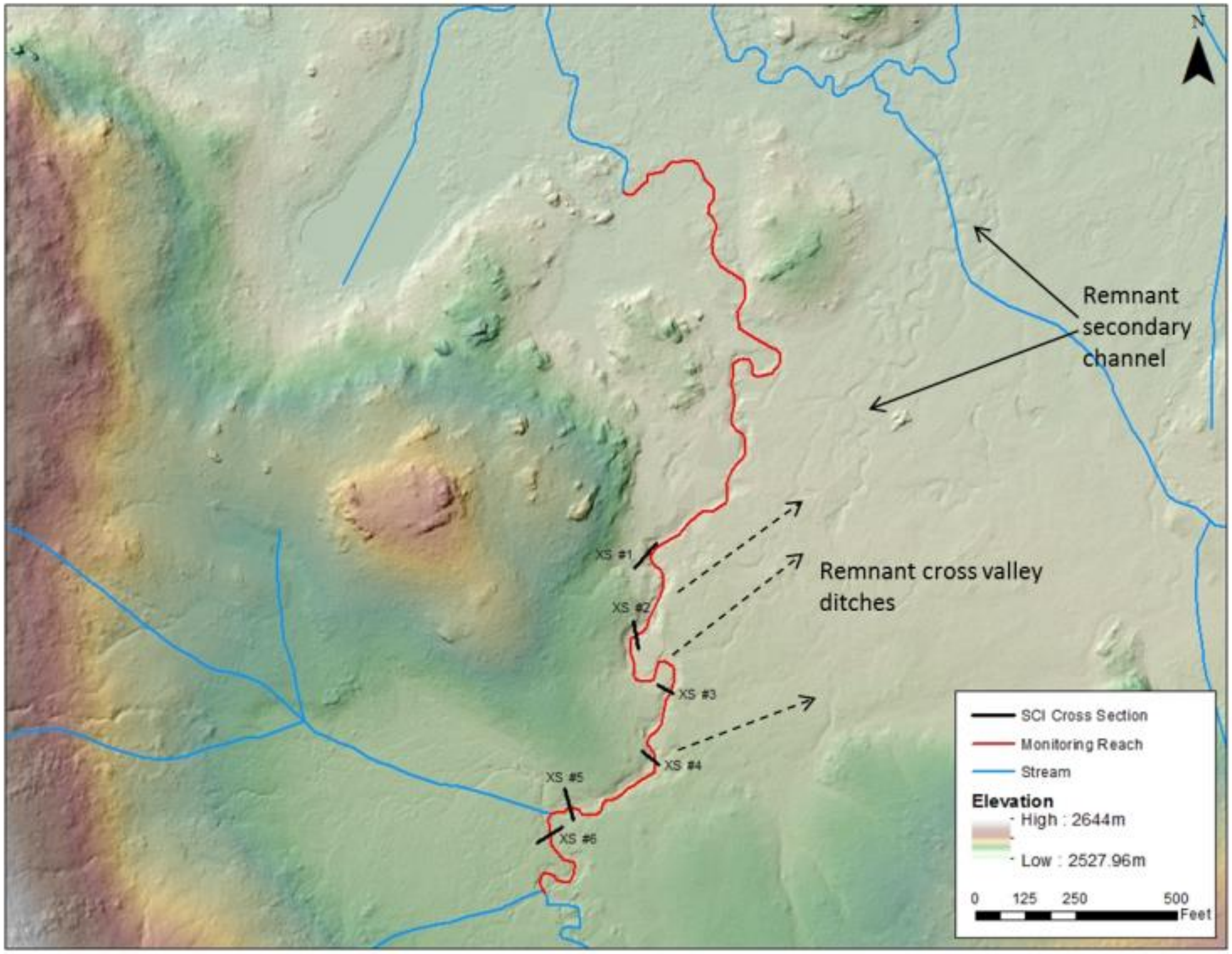

FIGURE 6 – 2009 LIDAR of Meiss Meadows and Meiss monitoring reach. Dashed arrows show the location of ditches leading off the main channel. The main channel also appears to follow higher ground next to the meadow (a possible highline canal placed strategically to control meadow wetness).

Big Meadow

The Celio family ran cattle in the Big Meadow area in the early 1900's; livestock were likely utilizing Big Meadow prior to this, but stocking levels in the area are uncertain. Earliest stocking records from 1925 to 1943 show that 193 cattle were grazed annually on Celio lands. Later the watershed became part of the Meiss allotment in 1960's. Stocking levels from 1982 on were of similar magnitude to that of Meiss meadow with a similar pattern of reduced animal numbers over time.

The 1937 flood event was likely an extreme runoff event in the Big Meadow watershed. Once again comparing 100-year runoff / drainage area ratio with the Caples runoff / drainage area ratio suggests a modern 100-year runoff / drainage area ratio of 70 CFS/mi^2, a considerable peak flow.

In contrast to stream response to flooding Meiss Meadow, the stream flowing through Big Meadow in 1940 **(FIGURE 7)** visually appears to have experienced nothing close to level of stream adjustments from flooding or water management strategies deployed at Meiss. Flooding appears to have had minor impact by adding some sediment to instream point bars, and there may have been some braiding from increased sediment supply upstream of the current monitoring reach. To add, there appears to have been some man-induced flow spreading onto topographic highpoint (the tongue-shaped flood deposit) about mid meadow where it appears that flash boarding may have been used to direct water out of the channel to this portion of the meadow resulting in some minor head cutting off these flow paths. After 1940, the channel settled into its current position and has not moved much over the past 72 years, based on visual inspection of the Big Meadow aerial photo record. The channel did incise some but the effects appear to be minor based on SCI cross section shape and channel confinement (entrenchment) data that will be presented later.

Similar to Meiss Meadow, the Forest Service identified resource impacts throughout the Allotment in the 1950s and began reducing stocking levels. In the following decades there was also growing concern regarding Lake Tahoe's water clarity. Stream channel erosion was thought to contribute to a steady decline in lake clarity (Murphy et al., 2001). This resulted in the Forest Service Lake Tahoe Basin Management Unit (LTBMU) modifying the grazing practices to reduce impacts to water quality. The allotment, as with Meiss Meadow was vacated in fall 2001 because the State of California water quality fecal coliform standard could not be met.

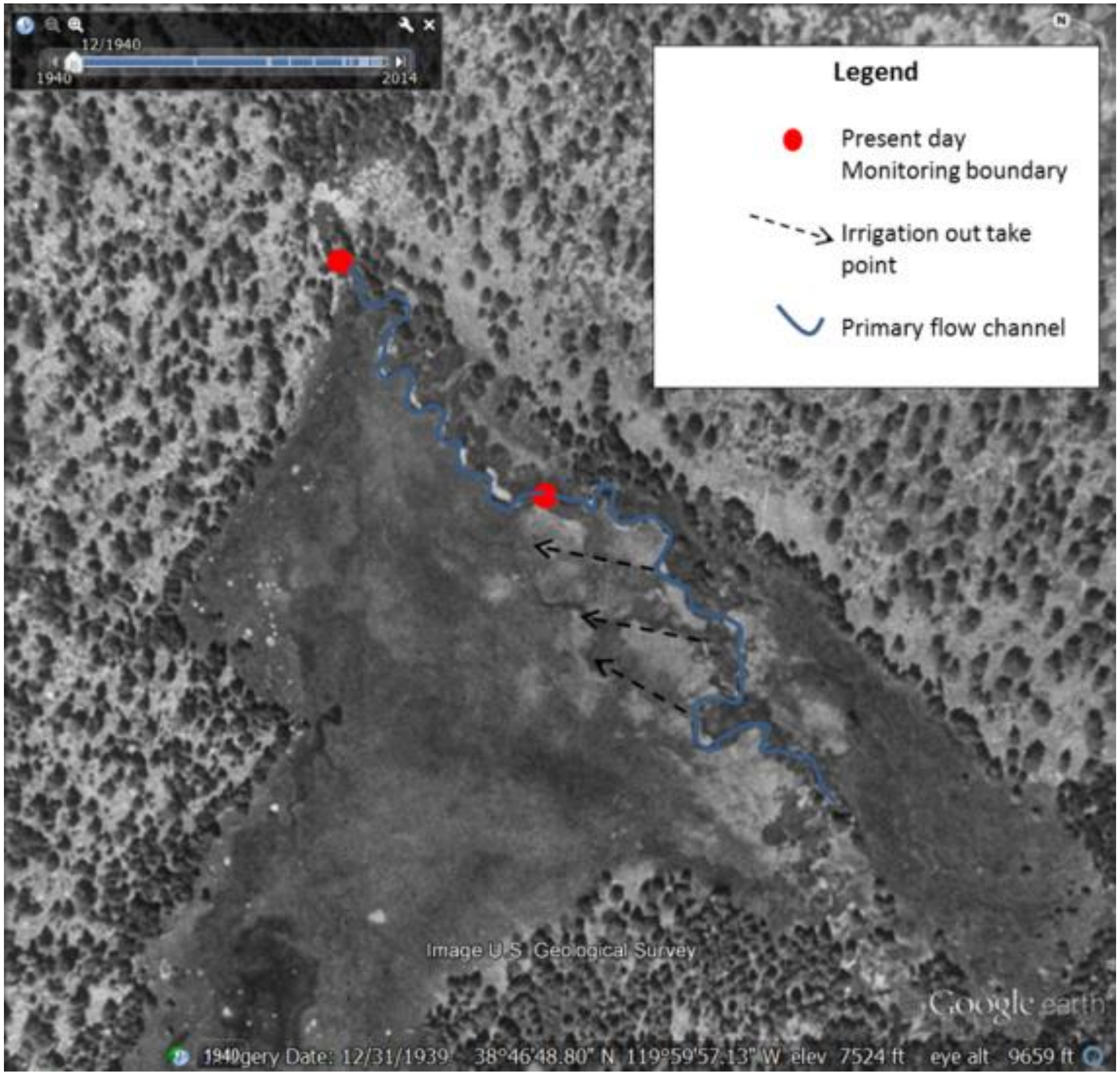

FIGURE 7 – 1940 Aerial Photo of Big Meadow and Big Meadow Monitoring Reach

Management Changes and Long Term Rest

In the early 1990s the USFS LTBMU began allotment assessment monitoring to determine what grazing system would provide forage but still protect meadow and stream channel resources. Pfankuch stream stability assessments during that time noted a high occurrence of eroding vertical banks a likely indicator of stream instability. Stream habitat assessments also indicated that shade and in-stream cover attributes were also degraded.

This data was presented in 1993 Environmental Assessment conducted by the LTBMU. The results of the Environmental Analysis led to a decision by the Forest Supervisor to propose a five to 15 year period of long term rest to allow meadow stream segments to recover and meet desired conditions; the rest period was to begin in 1995. The decision however, was appealed and overturned in part by the Regional Forester who felt the data did not adequately support the decision. A compromise resulted and the LTBMU was directed to implement stream restoration, conduct stream bank condition monitoring, install riparian exclosure fencing, and work with the permittee to modify practices to improve the stream condition throughout the Big Meadow and Meiss Meadow systems**.**

Around this time, a new monitoring protocol was developed to better assess stream conditions, meadows in particular, throughout the region. The Stream Condition Inventory (SCI) protocol, under development in 1995 and 1996, was intended to track stream and aquatic fish habitat conditions in response reaches (i.e. segments of streams sensitive to change from management practices). The LTBMU established SCI reaches in Meiss and Big Meadow in 1995 and repeated measurements in both reaches in 2001. During this period the January 1997 flood occurred, but the data presented indicates flood effects in the reaches may have been minor at best.

In addition to monitoring and resource protections administered by the LTBMU, there was coordination with the Lahontan Regional Water Quality Control Board (LRWQCB) to conduct monitoring on the allotment for water quality related to fecal coliform standards. Monitoring showed that from 1991 to 1997, exceedences of fecal coliform standards were correlated with grazing in Big and Meiss Meadows. The LRWQCB issued a Notice of Violation to the LTBMU in August 1999; the Notice stated that if coliform conditions did not improve, grazing on the Meiss Allotment may be subject to stricter controls or given an order to cease and desist. As monitoring results for fecal continued to show coliform standard exceedance during periods of active grazing, the holder of the grazing permit decided to vacate the allotment after 2001.

With the suspension of grazing the LTBMU continued SCI monitoring at both sites, repeating measurements at Big Meadow in 2007 and both sites in 2013 to determine whether stream channel condition trends would improve as a result of long term rest from cattle grazing. The following sections provide insight into the metrics used and results of these efforts.

SECTION 2.

Aquatic Habitat Monitoring Plan

Because SCI data collection began prior to grazing cessation, there was an opportunity to evaluate how the stream and meadow conditions were changing under total rest; keeping in mind that changes seen in stream attributes at these two sites may represent more than just a response to removing cattle. Changes such as hydrologic condition (climate) shifts or continued long-term adjustments from big floods in the past are also be part of the story.

The two monitoring reaches as noted earlier have unique characteristics, and so the data was evaluated in both sites individually. The nine attributes analyzed in the monitoring reaches are: cross section shape (bank full width-depth ratio and entrenchment ratio), pool characteristics (# of pools, pool-riffle ratio, and residual pool depth), stream bank stability, stream shade, percent fine particles less than 2mm on the channel surface, and particle size distribution focusing on the changes in D50 (diameter < 50cm).

In Meiss Meadow the monitoring reach is 1000 meters long. In Big Meadow, reach length was originally 850 meters, but reduced to 350 meters in 2010 to remove potential bias in the data collection. The decision to shorten the reach was made by the LTBMU Aquatics Program Leader based on 1) post- grazing development of beaver dams discovered in the upper 350 meters of the Reach and 2) the presence of a grazing exclusion (fenced ex-closure) in the upper 450 meters established back in 1996.

Permanent cross sections were established in both meadows in order to provide fundamental understanding of the relationships and trends in channel width and depth, streambed and stream bank shape, bankfull stage, degree of lateral confinement (entrenchment) etc. All of these are important attributes of channel condition and are often indirect indicators of the health of aquatic ecosystems.

Cross section data collection in Meiss began in 1995. Ten cross sections were established in the 1000 meter reach to monitor and analyze for desired future conditions (DFC), but the data processing was shelved when the decision was made to conduct SCI instead.

For the Meiss SCI three of ten original DFC cross sections were selected and measured in 1995 and 2001. Width-depth and entrenchment ratio measurements were taken; unfortunately the data was collected when bank full channel indicators were questionable due to grazing pressures at the time, as well as bed load sediment infusion to the stream from the 1997 flood. Therefore, most of the SCI cross section shape data for Meiss was not used in this analysis. Fortunately, the original DFC cross section data from 1995 was available for use. In 2013 the SCI field crew was able to successfully reoccupy and measure five of the original ten DFC cross sections. Also, the SCI permanent cross sections (2 and 3) match up well with DFC cross sections (4 and 6) which allowed a comparison of the 2001 SCI cross sections to the 1995 and 2013 DFC cross sections.

The reoccupation of DFC cross sections was fortuitous; however, the 1995 DFC data set didn't include width-depth and entrenchment ratio data, and the 2013 channel shape ratio data were not attempted by surveyors. To mitigate these shortcomings and to analyze data in a consistent manner, width-depth and entrenchment ratios were estimated indirectly using a one dimensional cross section flow analyzer version 9 from the NRCS website. The model run on the SCI cross section 1 and DFC cross sections 3, 4, 5, and 6, which was then compared to the same cross section data collected in 2013 analyzed in the same manner.

Running the model requires estimates of slope, gradient, and channel-floodplain roughness in a one dimensional flow energy equation to back calculate water stage and volume. Four initial steps were required to estimate width-depth and entrenchment ratios. First the bank full (1.5-year flood reoccurrence interval) flow volume was estimated from regional regression estimates using the USGS StreamStats program. Second the channel gradient at the cross sections was estimated from topographic maps and from old SCI 2001 data. Third a channel and floodplain roughness value were determined using Manning's roughness values from Chows 1959 open channel hydraulics publication; roughness was increased by 20 percent for the 2013 cross sections to qualitatively account for changes in channel shape and vegetative cover. Finally the model was run on the 1995 and 2013 cross sections (See **APPENDIX B** for model data, outputs, and output graphs).

From these model runs, estimates of width-depth ratio were determined by dividing the bank full width by flow area model values to get average bank full depth, then dividing bank full width by average depth for the width-depth ratio. For entrenchment ratio, the river stage at double the maximum bankfull depth measured off the bank full discharge output graph was used, then that stage value was modeled and the flow width (floodprone width) was measured off that output graph. The floodprone width was then divided by bankfull width to determine the entrenchment ratio.

In Big Meadow three permanent cross sections were established in 1995 and re-measured in 2001, 2007, and 2013. In some median width-depth or entrenchment ratios could not be calculated; however there was enough data to qualitatively evaluate changes in cross section shape and lateral flow confinement for the period of record.

Pool-Riffle ratio and Residual Pool Depth

Pools are an important component of habitat for aquatic organisms. They are important for different reasons to different aquatic species and may provide deep water and cool summer temperatures, winter refuge, and areas for rearing of fish and amphibians. They are also important components and indicators of channel morphology. Pool Riffle ratios values can vary, but a 1:1 ratio is thought to be reflective of higher quality habitat in general (Hunter and the Montana Land Reliance, 1990). Residual pool depth is a measure of the depth of the water left in the pools once stream flows are very low, or have ceased. In general deeper pools provide higher quality habitat and refuge areas for aquatic species.

Pool-riffle ratio and residual pool depths were measured in Meiss 1995, 2001, and 2013. A beaver at the downstream end of the reach backwatered the lower 260 meters of the reach in 2013 and so data on the upper 840 meters were compared from the three data sets for these two attributes. Big Meadow pool data was collected in the 850 meter reach 1995, 2001, and 2007; pool data that fell within the present day 350 reach were compared with the 2013 data.

Stream bank Stability and Stream Shade

In both reaches stream bank stability and shade are dictated by the quantity of stream bank vegetation. Stable stream banks are essential for achieving desired stream channel morphology. Stable banks maintain or help restore low width-depth ratio which in turn helps maintain a high water table, vegetative productivity, and favorable habitat for aquatic and riparian dependent wildlife.

Stream temperature, influenced by the amount of shade, can impact health, behavior, and survival of aquatic organisms. Streamside vegetation is a primary modulator of solar radiation in most meadow streams. Manipulation of riparian vegetation that negatively effects shade in aquatic systems is a key Forest Service management concern.

Stability and shade measurements were made along 50 equally spaced transects on the 1000 meter Meiss Reach, while at Big Meadow the 50 transects measured on the 350 meter Reach in 2013 are compared with subsets (data from the lower 350 meters) from the 1995, 2001, and 2007 data.

Riffle Particle Size Distribution

Streambed materials are key elements in the formation and maintenance of channel morphology. These materials influence channel stability, resistance to scour during high flow events, and area a supply of bed load to be routed and sorted throughout the channel. The amount and frequency of bed load transport can be critically important to fish spawning and other aquatic organisms that use stream substrate for cover, breeding, or foraging.

Particle size distribution can change over time as a result of management activities or even natural disturbances. In general, particle size distributions that contain a higher percentage of gravels and cobbles relatives to sand size particles or smaller, are more favorable to aquatic habitat.

Particle count data (was collected in the first four riffles at the start of the each monitoring reach at both sites in 1995 and 2013. Early particle surveyors collected 100 particles segregated into 10 size classes. In the recent 2013 the count increased 400 particles and segregated into 16 different size classes, gradations are based on USGS gravel Pebbleometer gradations. The data was entered into a particle analysis excel spreadsheet developed by Potyondy and Bundt to analyze for changes in the size distribution. Using this program with 1995 particle counts with fewer size gradations resulted in graphing variation, but not enough to obscure the interpretation of the changes occurring in surface particle characteristics at both sites over time.

SCI Results

Eight of the nine aquatic habitat health attributes have improved since 1995. Some attributes improved substantially (number of pools and pool riffle ratio) between 1995 and 2001, while others show slower but steady improvement over time.

Complete results are presented in the table below. Individual metric data (medians and standard deviation) are located in **APPENDIX C**

	Big Meadow			Meiss Meadow		
ATTRIBUTE	**1995**	**2013**	**Trend**	**1995**	**2013**	**Trend**
Median width-depth ratio	**NC**	**NC**	***Positive**	**40**	**19**	**Positive**
Median entrenchment ratio	**NC**	**NC**	***Positive**	**1.47**	**1.57**	**Positive**
# of pools	**7**	**19**	**Positive**	**18**	**28**	**Positive**
Pool riffle ratio	**0.15:1**	**1.7:1**	**Positive**	**0.6:1**	**1.5:1**	**Positive**
Median Residual Pool Depth (m)	**0.64**	**0.44**	**Negative**	**0.55**	**0.40**	**Negative**
Median % Shade	**2**	**25**	**Positive**	**15.5**	**26**	**Positive**
% stable stream banks	**40**	**0**	**Positive**	**12**	**3**	**Positive**
% streambed particles less than 2mm	**35**	**5**	**Positive**	**20**	**2**	**Positive**
Median (D50) particle size	**4**	**18**	**Positive**	**15**	**30**	**Positive**

NC = data not sufficient for median calculation * = Interpretation based on limited data

<u>Cross Section Shape Change</u>

Width-depth ratios (**APPENDIX A**) have decreased in Big Meadow at all three cross sections measured, however only sections 1 and 3 have data from 1995 to compare with 2013. Cross section 3 had the largest width-depth ratio decrease from 8.1 to 4.2 and cross section 1 decreased from 16.7 to 8.5. Over the last six years cross section 2 width-depth ratio has decreased from 20.6 to 18. Cross section 2 had split flow and a bank full top width greater to start with, and the change seen at this section may be representative of wider shallower segments of stream trending towards a narrower single thread flow as these areas recover over time. For single thread sections, **FIGURE 7** represents changes that occurred throughout most of the reach.

The entrenchment numbers at Big Meadow are inconsistent and there is not enough data to demonstrate a trend at any cross section numerically; however, nearly all entrenchment values on permanent cross sections collected over time exceeded a value of 2.2, at which the channel is considered minimally entrenched (Rosgen, 1996), a condition where flood flows spread out enough laterally to minimize channel energy and keep erosion at a natural level.

The channel might also be minimally entrenched upstream of the current monitoring reach, recalling that this reach was once 450 meters longer prior to 2010. In 2001, five randomly selected cross sections within the old 850 meter section had entrenchment values greater than three and a couple were measured at seven; unfortunately it is not clear if any of the random measurements were taken upstream of the present day reach, and so entrenchment changes throughout a larger portion of the meadow remain unknown currently.

In Meiss the median width-depth ratio for the cross sections dropped from 40 to 19 over the 18-year period. Most of the improvement occurred in the cross sections around the PCT. The trail is located on the topographic constriction and median width-depth ratio of these three cross sections (DFC 4, 5, and 6) was 52 dropping to 31 by 2013. **FIGURE 8** shows the changes occurring on the channel at the PCT visually. The two cross sections farther downstream of PCT are also narrowing with a width-depth ratio of 20.1 and 21 in 1995 dropping to 17.9 and 15 in 2013.

Median entrenchment ratios at Meiss also improved from 1.5 to 1.6 between 1995 and 2013. Most of the change occurred upstream of the PCT where the entrenchment ratio improved from 2 to 3 at cross section 5 and 1.5 to 2 at cross section 6. In these cross sections the channel was was wide when the allotment was active, but not so incised because of its depositional nature, and so the narrowing of the bankfull channel caused the positive shift in entrenchment. Median entrenchment below the PCT improved only slightly from 1.4 to 1.5.

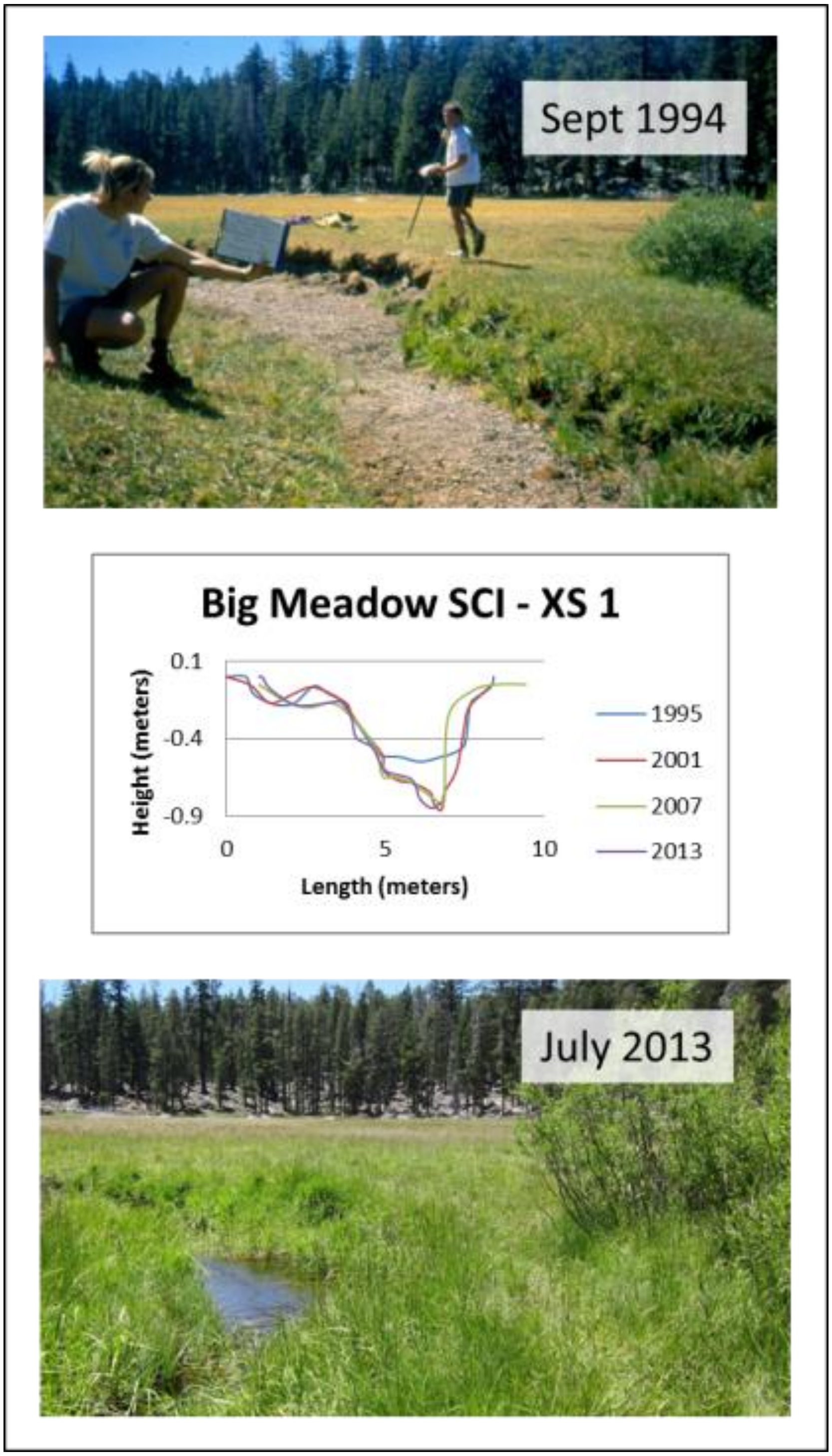

FIGURE 7 – Historic and recent photo taken approximately 10 meters downstream from cross section 1 in Big Meadow. The stream at the cross section showed some deepening that was probably in response to the 1997 flood, followed by narrowing as erosion resistant grasses grow in from channel bank edges.

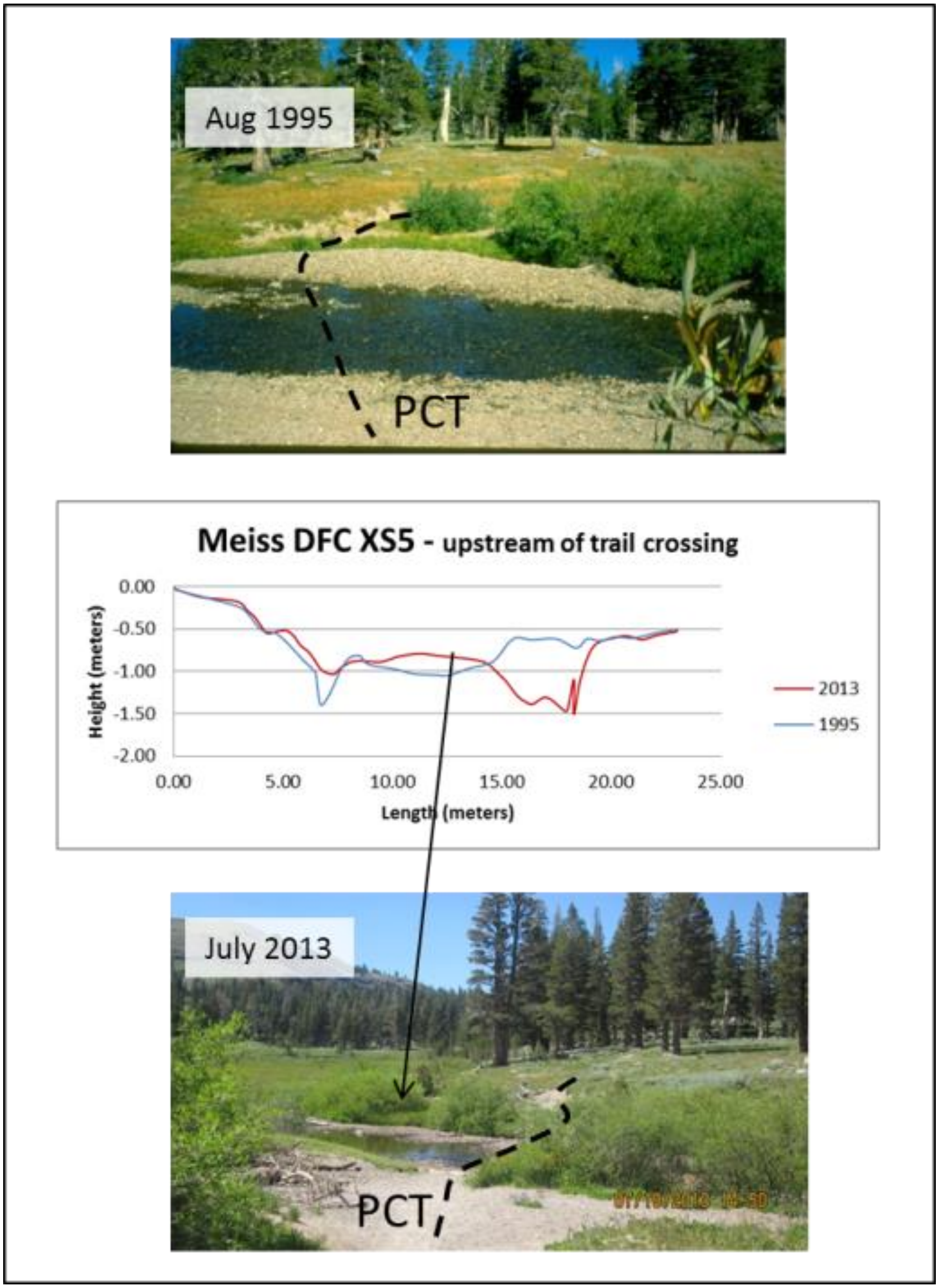

FIGURE 8 – photos and data showing changes cross section shape occurring on the creek near the PCT stream crossing at Meiss Meadows. Arrow from the cross section to 2013 photo shows is characteristic of bar formation and riparian vegetation colonization, characteristic of channel reorganization and vegetative response seen in other areas along the monitoring reach and throughout the meadow in general.

Pool Quality

The number of pools in Meiss Meadow increased from 18 to 27 between 1995 and 2001. Pool numbers in Big Meadow increased from 7 to 18 during the six year period. During that same time pool riffle ratio doubled in Meiss Meadow (from 0.6:1 to 1.3:1) and increased by an order of magnitude in Big Meadow (from 0.15:1 to 1.8:1). These are very interesting results and an interpretation will be presented in the discussion section of this report. The pool-riffle ratios at both sites steadied between 2001 and 2013, with the ratio at Meiss of 1.5:1 and at Big Meadow 1.7:1.

Curiously, median residual depth steadily decreased from 0.64 m to 0.44 m at Big Meadow from 1995 to 2013, and 0.50 m to 0.40 m at Meiss Meadow from 1995 to 2013. This is the only aquatic habitat attribute exhibiting a downward trend.

Percent Shade

Median percent stream shade has increased steadily at both sites since 1995. Median shade at Big Meadow was just 2 percent in 1995 and increased to 27 percent by 2013. In Meiss median shade was 15 percent in 1995 increasing to 26 percent in 2013. **FIGURE 9** is characteristic of vegetative cover change that resulted in increased shade at Big Meadow.

Bank Stability

Stream bank stability has increased steadily since 1995. The percent of stable banks grew from 50 percent in 1995 to 73 percent in 2013 in Big Meadow. In Meiss meadow many of the banks were already stable, and so the increase was much smaller with stability increasing from 76 to 78 percent. Of the banks that were not rated as stable most were rated as vulnerable by 2013, rather than unstable; the percent unstable banks was measured at zero at Big Meadow and just 3 percent at Meiss Meadow. **FIGURE 10** shows an example of near channel vegetation change in Meiss Meadow indicates bank stability.

Particle Size Distribution

Streambed surface particle size distributions also improved over the last 18 years. The percentage of particles less than 2 mm decreased from 36 to 5 percent in Big Meadow, and from 20 to 2 percent in Meiss Meadow. The median (D50) particle size increased from 4 to 18 mm at Big Meadow, and from 15 to 30 mm at Meiss Meadow.

FIGURE 9 – Photos of the change in vegetative cover that caused stream shade to increase in Big Meadow.

FIGURE 10 – Vegetation changes leading to improved stream bank stability in on the Upper Truckee in Meiss Meadows. Boulders are circled as datum for comparison.

SECTION 3

Discussion

The data analysis in this study strongly supports that aquatic habitat conditions for most metrics have improved in both reaches resulting in narrower channels, more pools, and a much greater percentage of pool area. In addition, more instream shade, greater percentage of stable banks, fewer riffle fines, and coarser riffles are apparent.

The fact that all metrics except for one (median residual depth) show a positive trend, there is a "weight of evidence" which suggests aquatic habitat recovery is taking place in these reaches. The advantage of multiple attribute monitoring, especially when the attributes are interrelated, can better explain level of improvement or impact to aquatic health. It also allows for the use of surrogates if data from certain metrics measured is less accurate.

The following three examples demonstrate the richness of the SCI multi-metric evaluation:

1) Data collected between 1995 and 2001indicate rapid increase of number of pools and pool area in both reaches while cattle were still grazing the allotment. Based on this one result, the response would seem to indicate that grazing could have continued after a short period of rest. However data from six other attributes suggest habitat improvements were just starting to occur, supporting the idea that it would have been premature to return cattle to the allotment.

2) Entrenchment data (degree of lateral confinement) in Big Meadow had inconsistencies that make it difficult identify the trend in this metric. Fortunately, there is cross section width-depth ratio data, visual observations, and bank stability data -- all of which suggest entrenchment ratio is moving in a positive trend. By utilizing a suite of SCI metrics for data collection, resource professionals can help bridge the gap when certain data uncertainties exist.

3) Both monitoring reaches showed a steady decrease in median residual pool depth, a critical variable for fish survival when isolated pools are the only surface water available. By itself the median depth value suggests that rest from livestock grazing or other watershed processes could be negatively impacting fish survival during intermittent flows.

The trends seen in related SCI pool quality data at both reaches suggest otherwise. For example: the standard deviation of residual pool depth increased over the last 18 years indicating there are still some deeper pools for the larger adult fish, and plenty other pools at varying depth that may provide habitat for a greater range of fish sizes. Instream shade and width-depth ratio also increased through time suggesting that temperatures are likely cooler and more hospitable for aquatic life, even if some pools are not as deep.

Figure 11 - Photo of channel and confining bank conditions (top of confining bank shown with white line) pre and post grazing. Surrogate data indicates a slight improvement in the Big Meadow entrenchment ratio.

Aquatic Habitat Condition and Climate Change

Now that the monitoring areas are well on their way to recovery, their continued improvement will be important in the face of climate change. Current science indicates that the climate is changing in the Tahoe Basin and throughout the west. Climate change predictions (Coats et al, 2010) indicate there will be similar seasonal precipitation amounts, but most precipitation traditionally in the form of snow, will fall as rain. Climate change research also predicts:

- upward trends in minimum and maximum day time temperatures,
- earlier snowmelt and runoff during the water year, and decreases in the hydrologic flow-duration,
- some increases in drought severity, especially toward the end of the century,
- dramatic increases in flood magnitude in the middle third of the century.

At Big Meadow, climate change effects may be mitigated some by further narrowing of the stream channel over time as erosion resistant grass and shrub cover becomes more robust. This change has positive effects as the resistance to erosion tends to promote channel stability if flooding severity increases. Over time pools will likely deepen further if the channel continues to narrow. Deeper pools and increased shading will be important for creating temperature refuges during extended droughts or reduction in snow pack. Coarsening of the streambed surface layer will also be important for maintaining high quality spawning habitat, which is beneficial to resident or restored fish populations having to face threats from climate change.

Another mitigating factor in Big Meadow is the presence of beavers that help maintain late season ground water levels that promote wetter surface conditions and persistence of grasses that provide erosion resistance. This condition should be evaluated periodically (at both meadows) to ensure that beaver dams are not having an adverse effects on hydraulics or riparian vegetation condition.

In Meiss Meadow above the PCT, significant lowering of width depth ratios and decreasing stream confinement will permit more flow spreading and energy reduction if flood intensity increases as predicted. Sediment influx may actually increase because of sediment source erosion and proximity to the meadow above the PCT. A hydrologically connected channel with erosion resistant vegetative cover however, affords this area the highest probability of withstanding high intensity flooding by providing energy reduction and the spreading of flows over the floodplain.

Conclusion

Data shows that Big Meadow and Meiss above the PCT have recovered to a more functional state in terms aquatic habitat condition, a trend that will likely continue over the short term. Longer term climate change effects and habitat quality condition is less certain, however the current habitat recovery trends and factors such as presence and persistence of beavers, seem to suggest that these two meadow stream segments are likely more resilient to impacts related to climate change than originally thought.

In Meiss Meadow below the PCT, although aquatic habitat conditions have improved. If climate impacts occur over the long term, there could be periods of stream corridor instability if flooding intensity increases because erosive forces would be higher in this confined section of stream. Stream entrenchment would also likely impact ground water levels on the eastern edge of the river below the PCT. Premature meadow aquifer drainage would be exacerbated if there were less water available later in the season as climate change models are predicting. The current condition suggests that there may be a need for future management action to restore hydrologic connectivity on the Upper Truckee River in Meiss Meadows below the PCT crossing, which bears watching.

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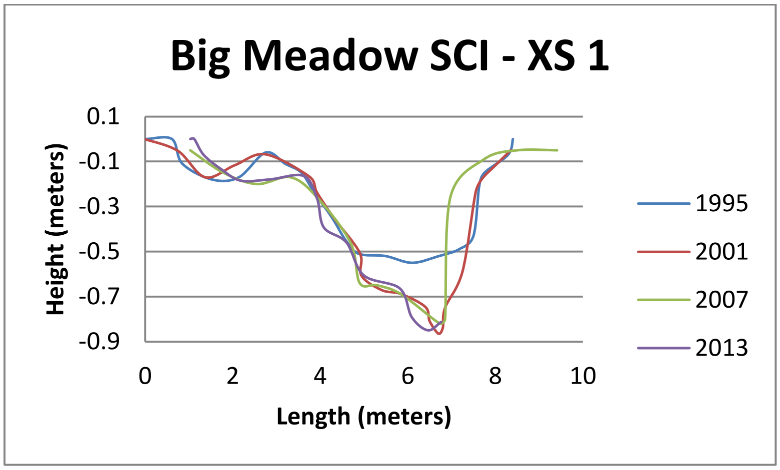
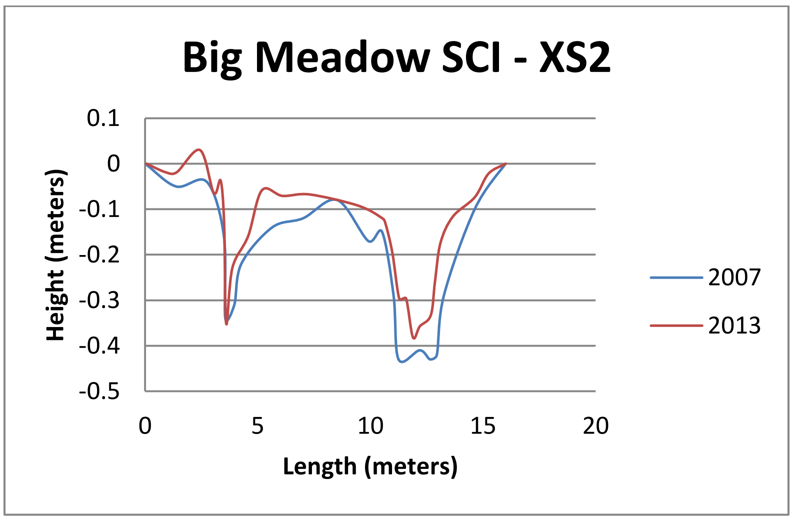
APPENDIX A

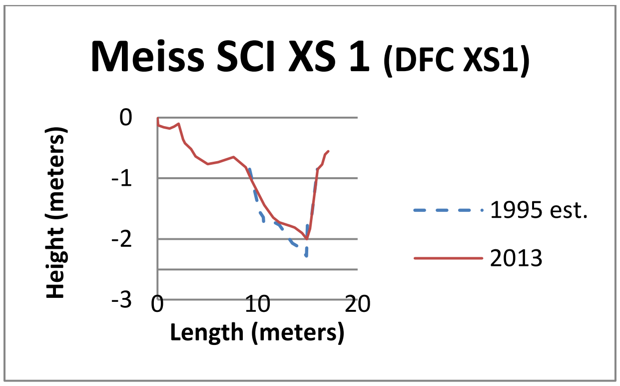
Permanent Cross Sections and Cross Section Shape Data

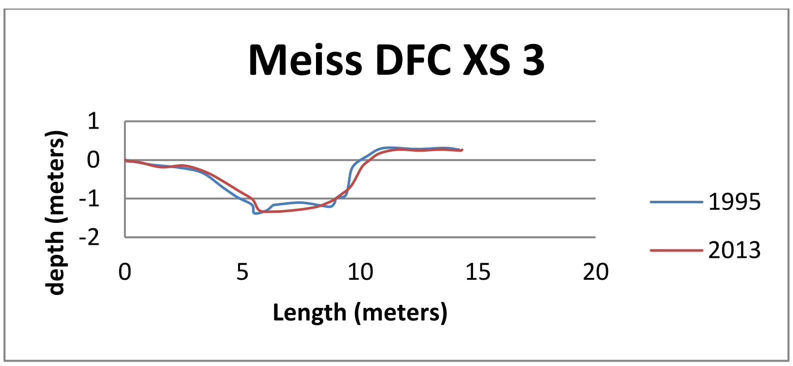


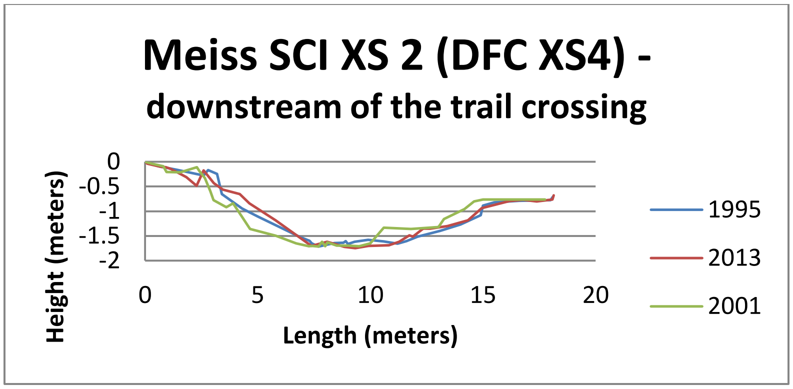


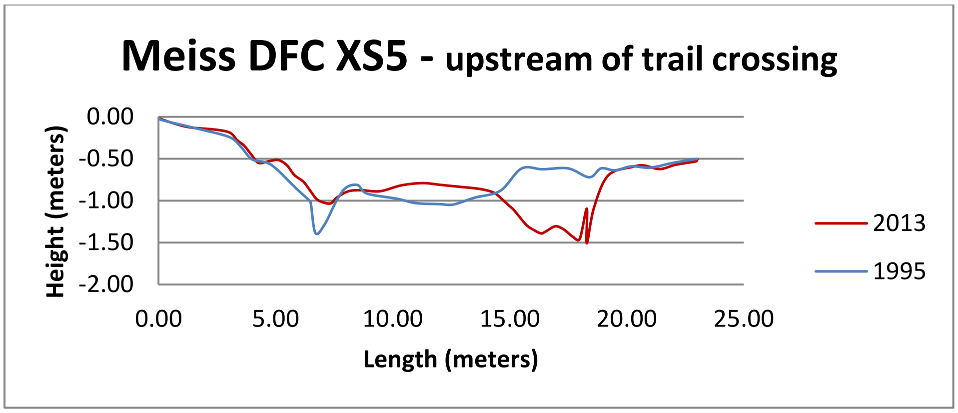
Big Meadow SCI Bankfull W/D Ratio				
Year	XSEC1	XSEC2	XSEC3	Median W-D ratio
1995	16.72	NR	8.08	NC
2001	9.05	NR	9.06	NC
2007	8.69	20.65	4.37	8.69
2013	8.5	18	4.2	8.5
NC = not recorded / NC = not calculated				

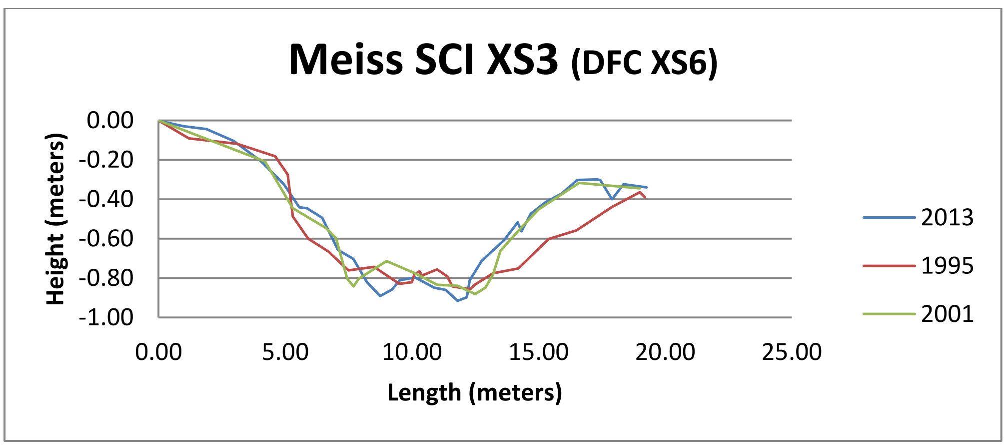
Big Meadow SCI Entrenchment Ratios										
Entrenchment Ratio - Permanent XS				Median Entrenchment ratio	Entrenchment ratio - random cross sections					Median Entrenchment ratio
Year	XSEC1	XSEC2	XSEC3		Random 1	Random 2	Random 3	Random 4	Random 5	
1995	16	NR	8	NC	NR	NR	NR	NR	NR	NR
2001	3+	NR	3+	NC	3	3	3	4.1	6.7	3
2007	32	2	14	14	NR	NR	NR	NR	NR	NR
2013	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
NR = not recorded / NC = not calculated										











Miess Meadows DFC bankfull WD ratio						
YEAR	XS 1 (sci)	XS3	XS4 (sci)	XS5	XS6 (sci)	Median
1995	20.1	21	40	51.6	62.4	**40**
2013	17.9	15	31.4	19	36.8	**19**

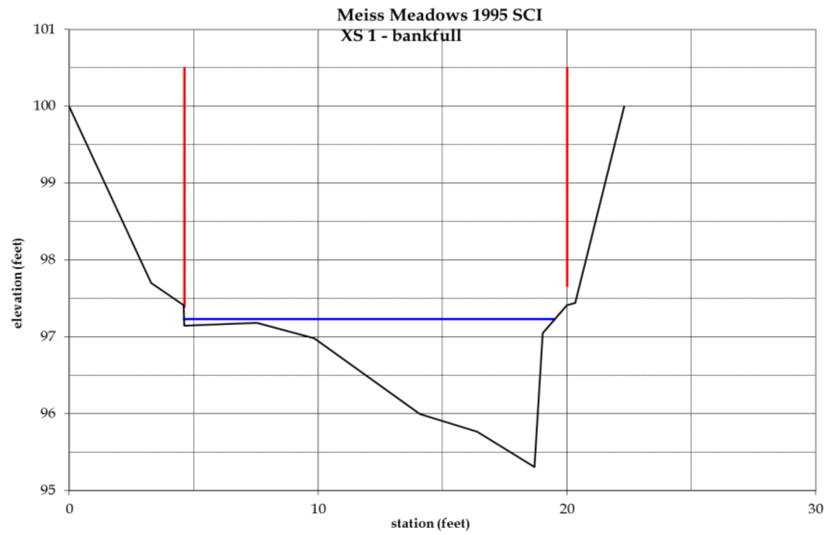
Miess Meadows DFC Entrenchment ratio						
YEAR	XS 1 (sci)	XS3	XS4 (sci)	XS5	XS6 (sci)	Median
1995	1.3	1.3	1.47	2	1.5	**1.47**
2013	1.44	1.4	1.57	3	2	**1.57**

APPENDIX B – Meiss Cross Section Modeling Output Data

Meiss Meadows 1995 SCI XS1 hydraulic properties for bankfull water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
97.23	11.03	16.62	0.66	14.90	0.74	0.03	0.12	416.76	25.01	2.27	0.15

average bf depth = 0.74 **Bankfull (top width / average depth) WD ratio = 20.1**



Meiss Meadows 1995 SCI XS1 hydraulic properties for floodprone water surface elevation:

w.s. elev	flow area	wetted P	hydr. radiu	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
99.16	46.09	23.71	1.94	20.46	2.25	0.04	0.10	3291.68	197.50	4.29	0.44

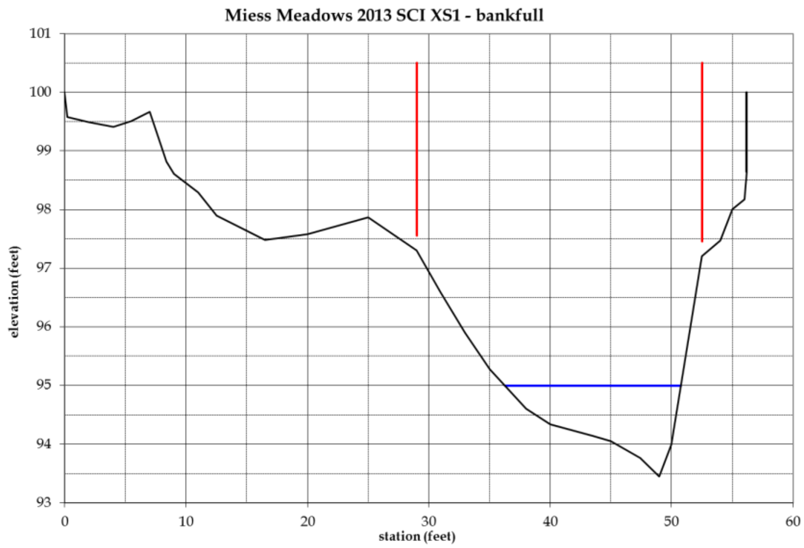
Entrenchment ratio (FP width / BF width) = 1.3

Cross Section 1 -1995

Meiss Meadows 2013 SCI XS1 hydraulic properties for bankfull water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis.	conveyance	discharge	velocity	shear
94.99	11.82	15.25	0.77	14.51	0.81	0.035	0.16	423.34	25.40	2.15	0.17

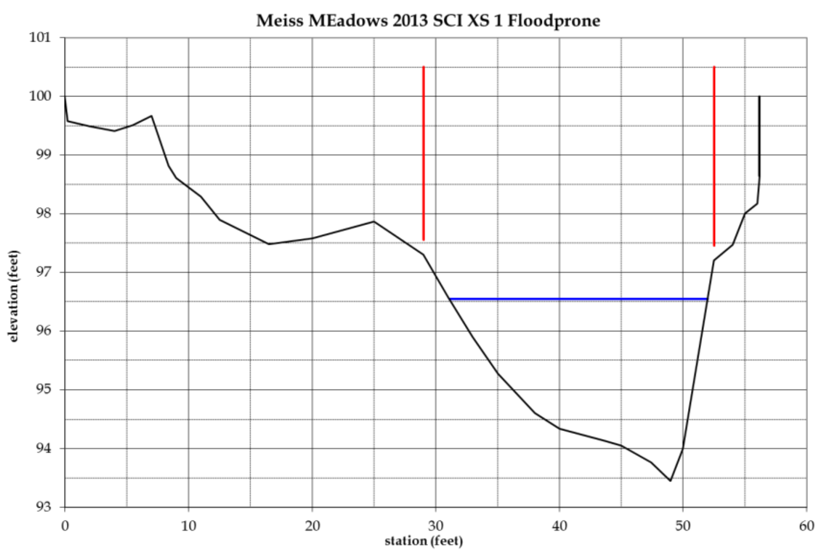
average bf depth = 0.81 **Bankfull (top width / average depth) WD ratio = 17.9**



Meiss Meadows 2013 SCI XS1 hydraulic properties for floodprone water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis.	conveyance	discharge	velocity	shear
96.6	39.7	22.6	1.8	20.9	1.9	0.035	0.12	2455.10	147.31	3.71	0.39

Entrenchment ratio (FP width / BF width) = 1.44

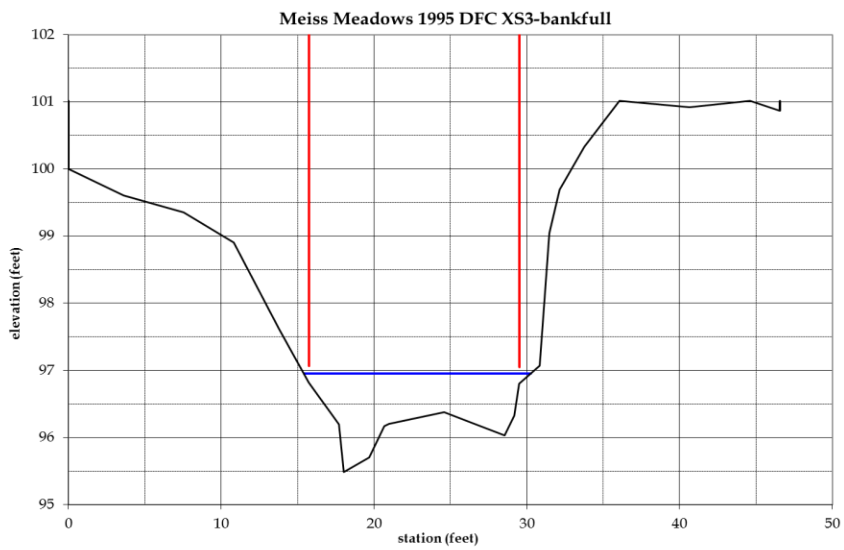


Cross Section 1 - 2013

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis.	conveyance	discharge	velocity	shear
96.95	10.72	15.88	0.67	14.84	0.72	0.03	0.11	424.21	25.45	2.37	0.15

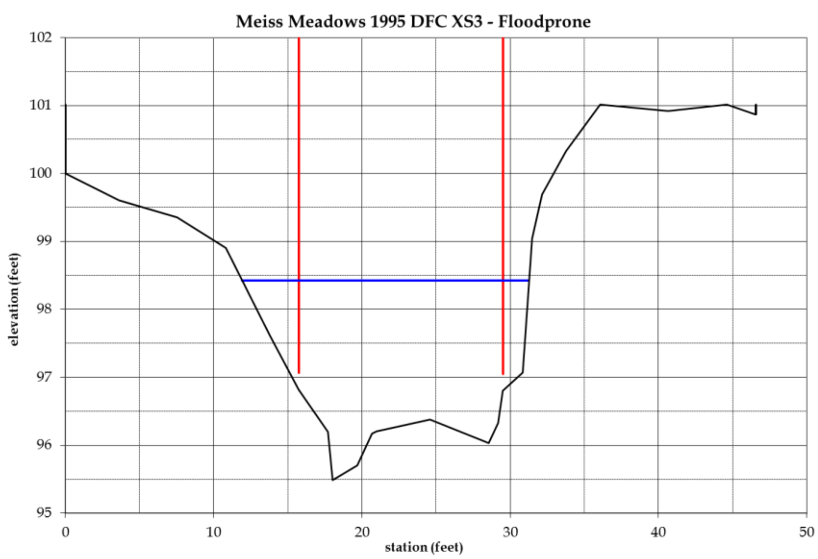
average bf depth = 0.72 **Bankfull (top width / average depth) WD ratio = 21**



hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radiu	top width	hydr. depth	n value	darcy-weis.	conveyance	discharge	velocity	shear
98.42	36.25	21.68	1.67	19.35	1.87	0.036	0.08	2648.31	158.90	4.38	0.38

Entrenchment ratio (FP width / BF width) = 1.3

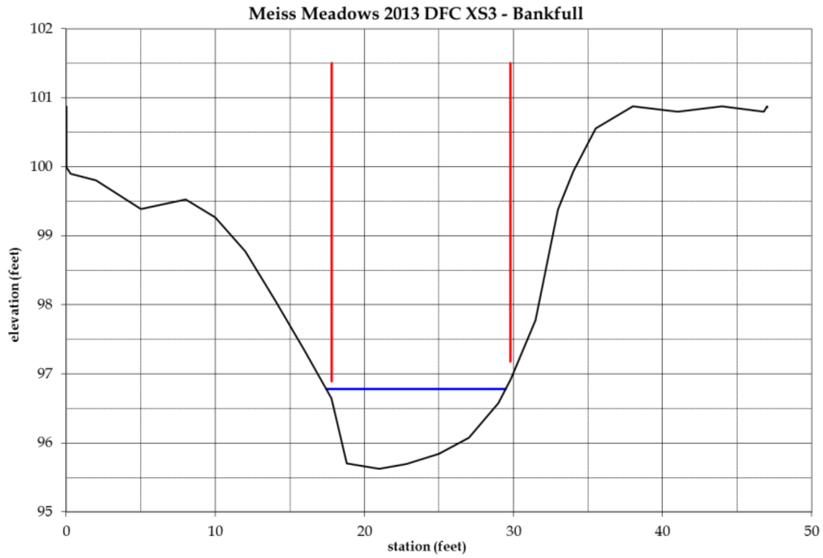


Cross Section 3-1995

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
96.78	9.91	12.55	0.79	12.02	0.82	0.03	0.1	426.7	25.6	2.6	0.2

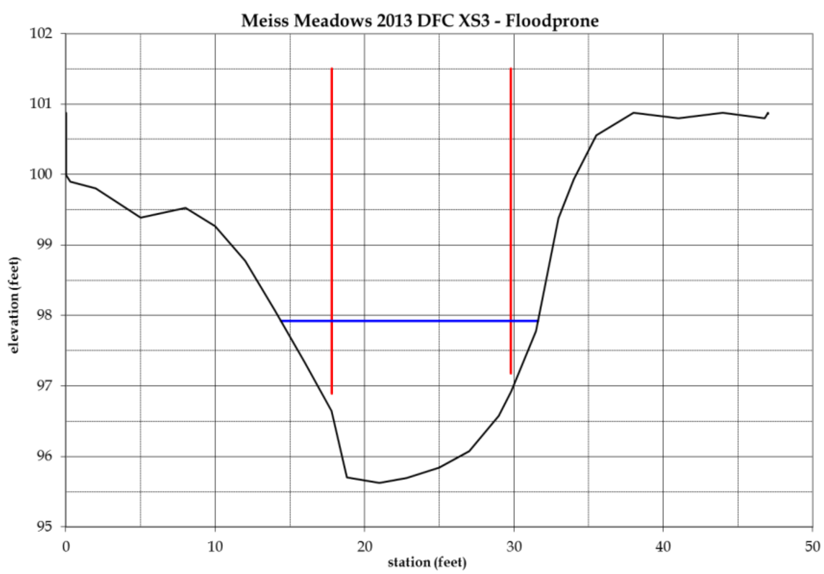
average bf depth = 0.82 **Bankfull (top width / average depth) WD ratio = 15**



hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
97.9	26.7	18.2	1.5	17.2	1.5	0.042	0.08	1832.6	110.0	4.1	0.3

Entrenchment ratio (FP width / BF width) = 1.4

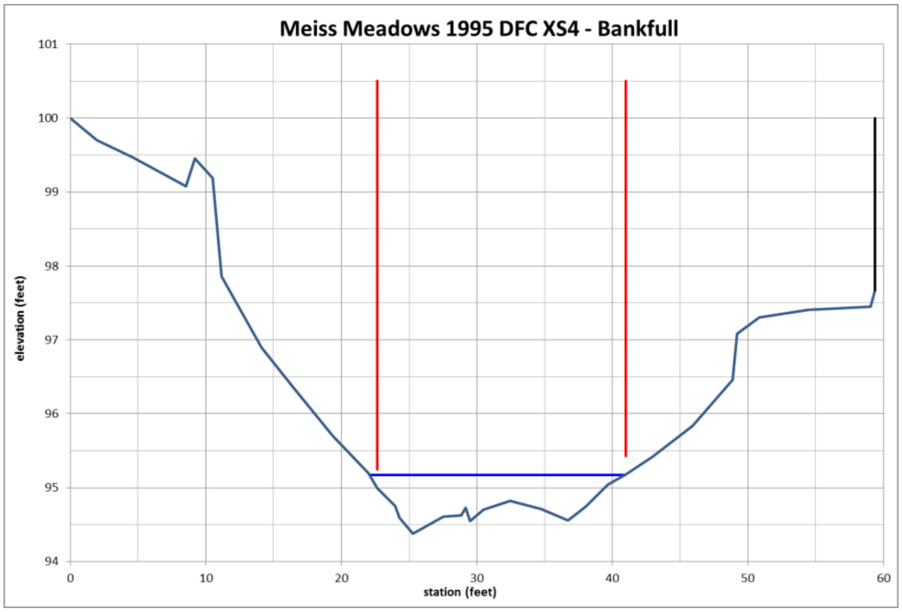


Cross Section 3-2013

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
95.17	8.43	19.07	0.44	18.81	0.45	0.04	0.2	184.0	25.0	3.0	0.5

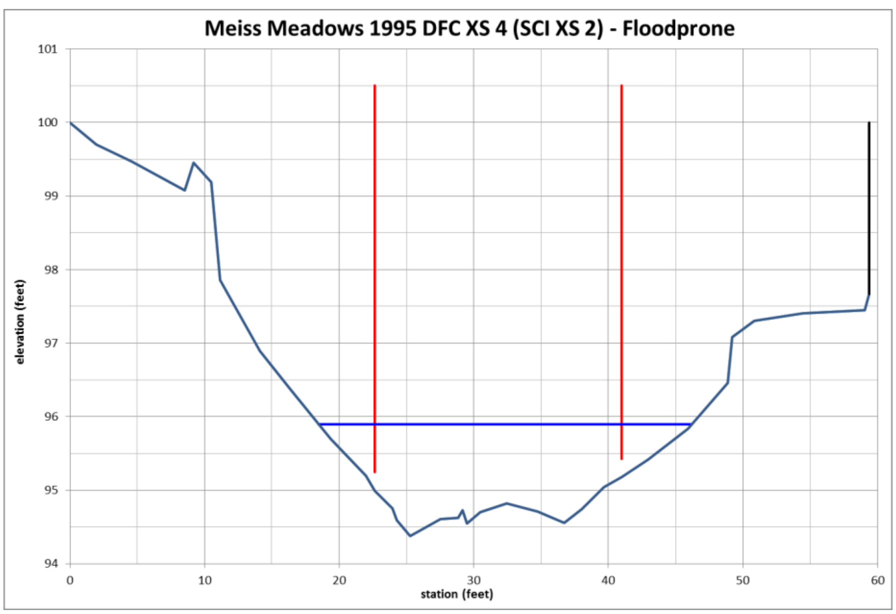
average bf depth = 0.47 **Bankfull (top width / average depth) WD ratio = 40**



hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
95.900	25.574	28.123	0.909	27.744	0.922	0.044	0.17	960.56	130.30	5.09	1.04

Entrenchment ratio (FP width / BF width) = 1.47

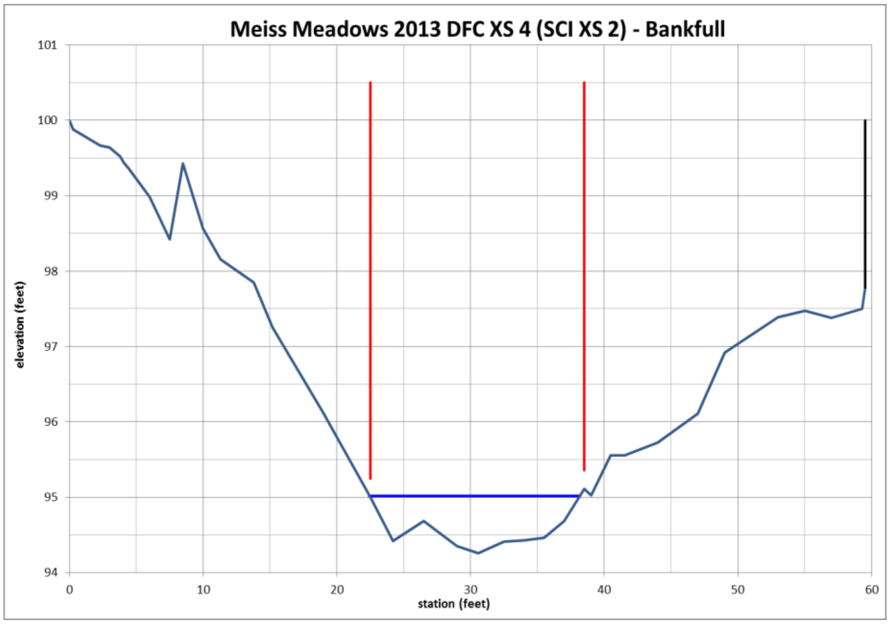


Cross Section 4-1995

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
95.0	7.9	16.0	0.5	15.7	0.5	0.04	0.2	185.7	25.2	3.2	0.6

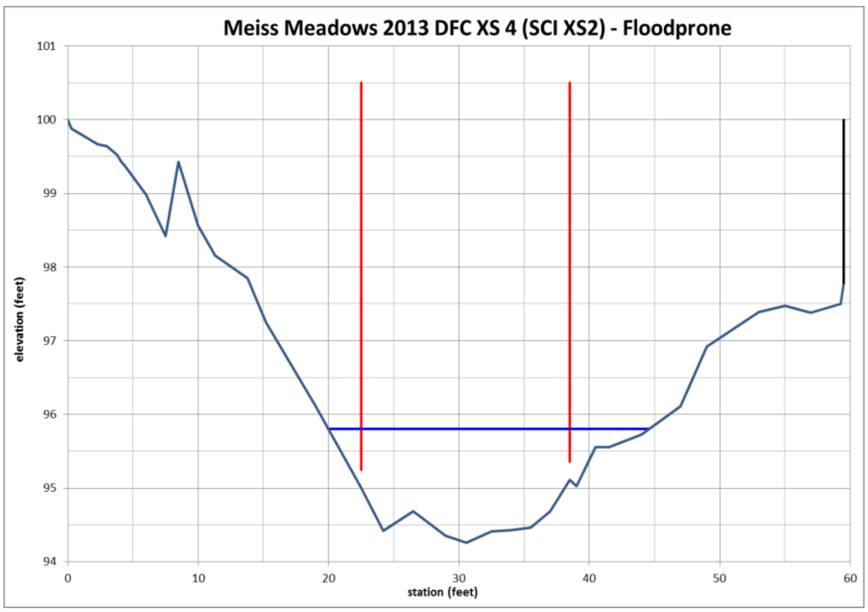
average bf depth = 0.5 **Bankfull (top width / average depth) WD ratio = 31.4**



hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
95.8	23.2	25.0	0.9	24.6	0.9	0.05	0.2	911.6	123.7	5.3	1.1

Entrenchment ratio (FP width / BF width) = 1.57

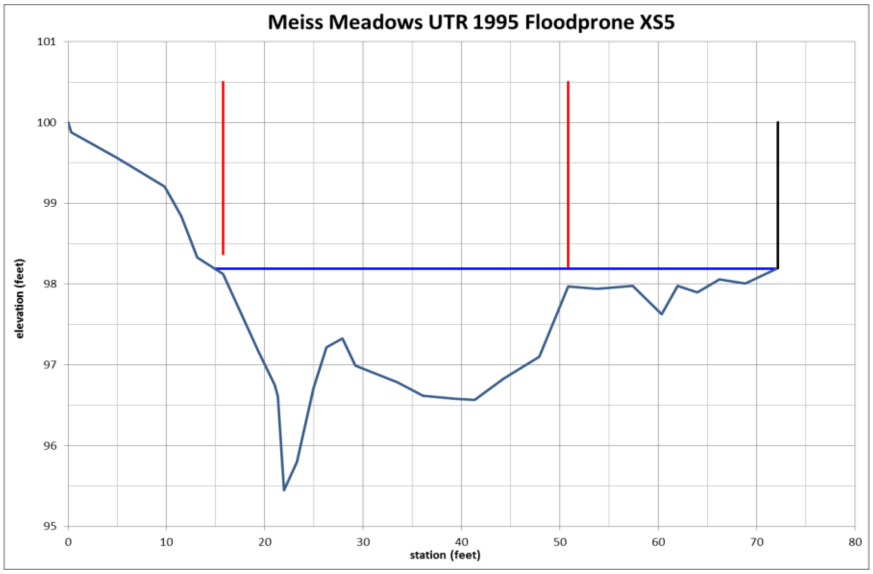


Cross Section 4-2013

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radiu	top width	hydr. deptl	n value	darcy-weis. f	conveyance	discharge	velocity	shear
98.19	50.49	58.66	0.86	57.11	0.88	0.04	0.08	2664.62	159.88	3.17	0.19

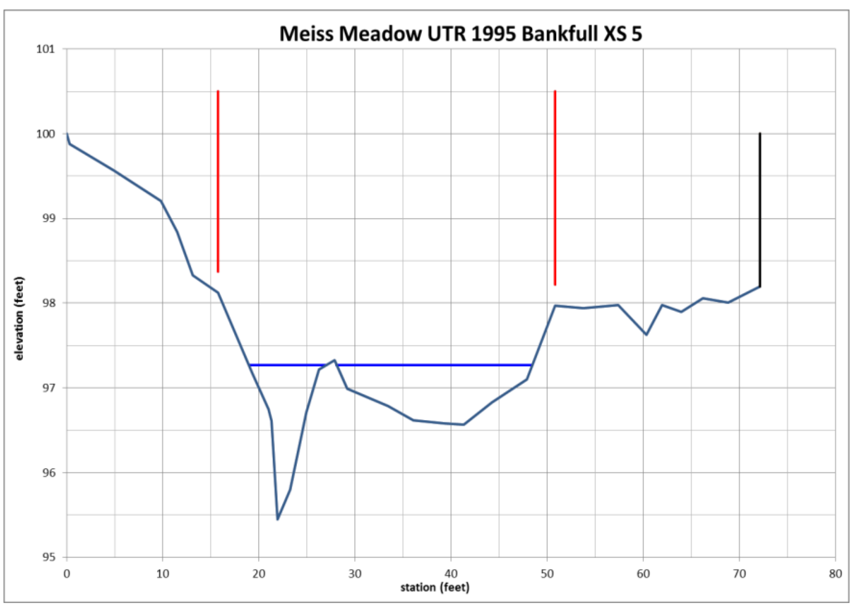
Entrenchment ratio (FP width / BF width) = 2.0



hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radiu	top width	hydr. deptl	n value	darcy-weis. f	conveyance	discharge	velocity	shear
97.3	15.4	29.6	0.5	28.4	0.5	0.035	0.2	424.5	25.5	1.6	0.1

average bf depth = 0.55 **Bankfull (top width / average depth) WD ratio = 51.6**

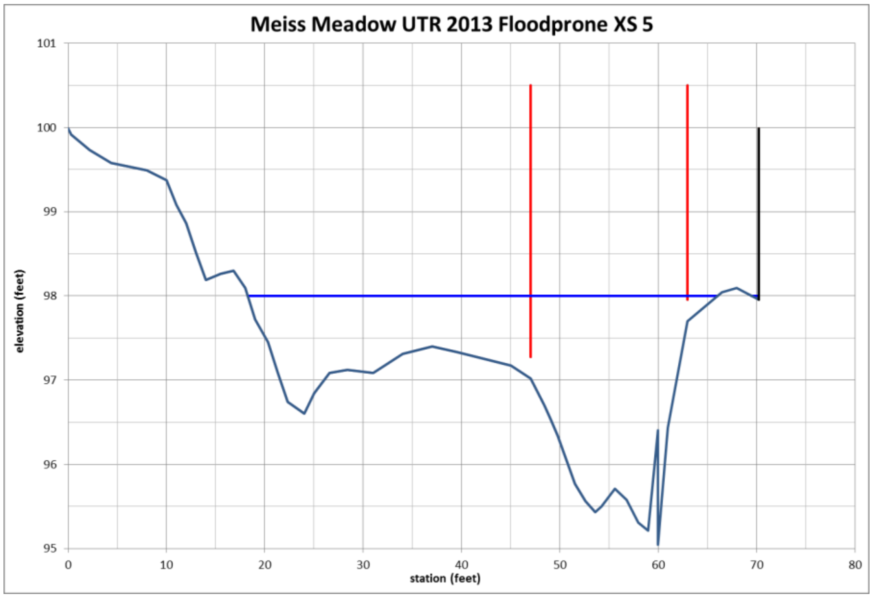


Cross Section 5-1995

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
98.00	55.75	52.11	1.07	48.57	1.15	0.059	0.20	2090	125	2.25	0.24

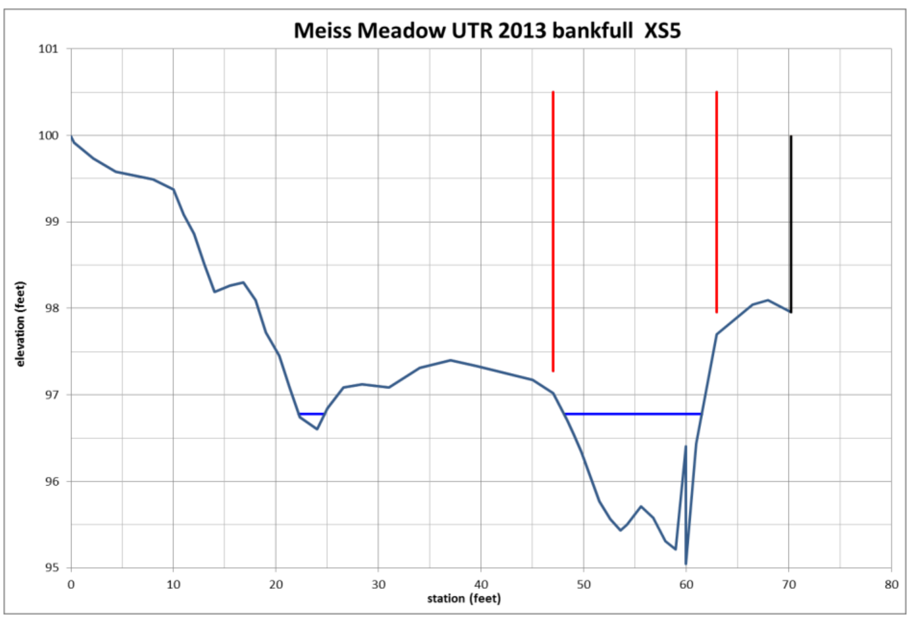
Entrenchment ratio (FP width / BF width) = 3.0



hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	conveyance	discharge	velocity	shear
96.8	13.4	19.0	0.7	16.0	0.8	0.04	0.2	421.6	25.3	1.9	0.2

average bf depth = 0.84 **Bankfull (top width / average depth) WD ratio = 19.0**

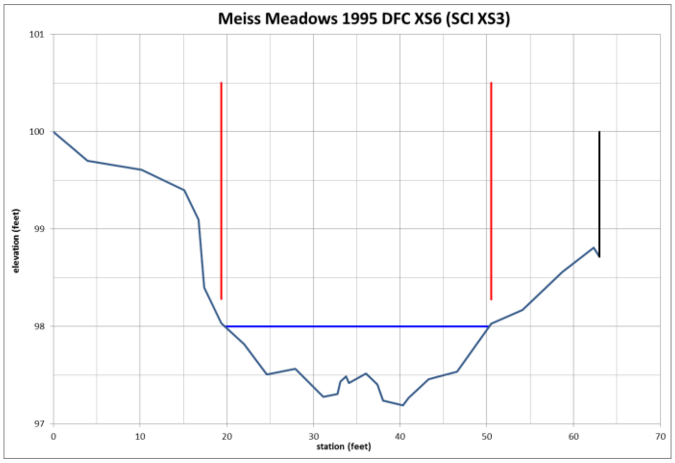


Cross Section 5-2013

Meiss Meadow 1995 DFC XS 6 hydraulic properties for bankfull water surface elevation:

w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis.	conveyance	discharge	velocity	shear
98.0	14.9	30.7	0.5	30.6	0.5	0.032	0.2	429.9	25.8	1.7	0.1

average bf depth = 0.49 **Bankfull (top width / average depth) WD ratio = 62.4**



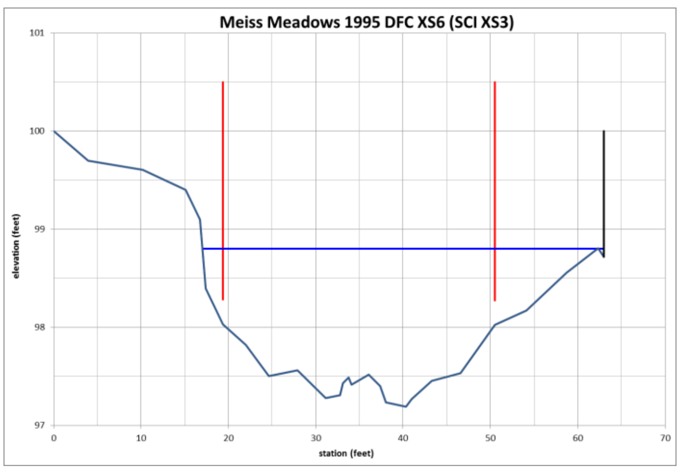
Meiss Meadows 1995 DFC XS 6 hydraulic properties of floodprone width for a given water surface elevation:

hydraulic properties for given water surface elevation:

w.s. elev	flow area	wetted P	hydr. radiu	top width	hydr. deptl	n value	darcy-weis	conveyanc	discharge	velocity	shear
98.80	46.08	46.23	1.00	45.84	1.01	0.033	0.10	2323.51	139.41	3.03	0.22

Maximum calculatable surface elevation = 98.8

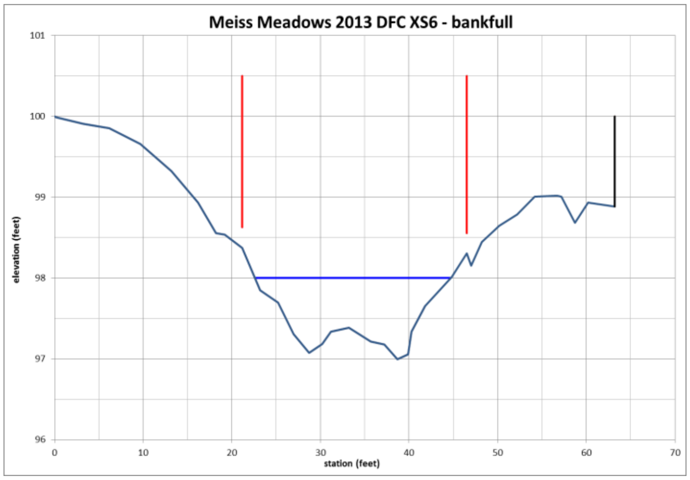
Entrenchment ratio (FP width / BF width) = 1.5 +; Water surface extends beyond cross section



Cross Section 6-1995

Meiss Meadow 2013 DFC XS 6 hydraulic properties for bankfull water surface elevation:											
w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	:onveyance	discharge	velocity	shear
98.0	13.2	22.3	0.6	22.1	0.6	0.033	0.15	418.08	25.09	1.90	0.13

average bf depth = 0.6 **Bankfull (top width / average depth) WD ratio = 36.8**

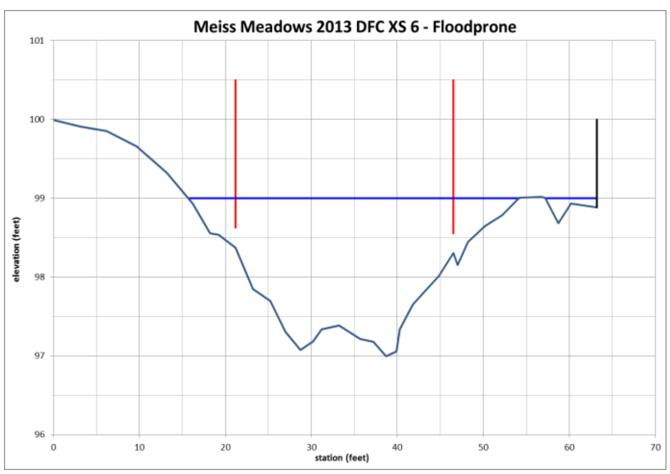


Meiss Meadow 2013 DFC XS 6 hydraulic properties for floodprone water surface elevation:											
w.s. elev	flow area	wetted P	hydr. radius	top width	hydr. depth	n value	darcy-weis. f	:onveyance	discharge	velocity	shear
99.00	43.73	45.07	0.97	44.44	0.98	0.039	0.09	2305.9	138.4	3.16	0.22

Maximum calculatable surface elevation = 99.0

Floodprone surface elevation = 99. floodprone width 44+ meters

Entrenchment ratio (FP width / BF width) = 2.0 +; Water surface extends beyond cross section



Cross Section 6-2013

APPENDIX C – Stream Attribute Data

BIG MEADOW POOL DATA					
YEAR	**1995**	**2001**	**2007**	**2013**	**ATTRIBUTE TREND**
# of pools	7	18	19	19	**Positive**
Pool riffle ratio	0.15:1	1.8:1	7.4:1	1.7:1	**Positive**
Median Residual Pool Depth	0.64	0.45	0.32	0.44	**Negative**
ST. Dev Residual Pool Depth	0.20	0.17	0.34	0.22	**Positive**

BIG MEADOW MEDIAN SHADE					
YEAR	**1995**	**2001**	**2007**	**2013**	**ATTRIBUTE TREND**
# of data points	20	20	17	18	-
MEDIAN SHADE	2	11	9	27	**Positive**
STD. Dev. shade	13	23	17	21	**Variable**

BIG MEADOW STREAMBANK STABILITY					
YEAR	**1995**	**2001**	**2007**	**2013**	**ATTRIBUTE TREND**
# of data points	40	40	34	34	-
%stable	50	45	82	73	**Positive**
%vulnerable	10	50	5	27	**Variable**
%unstable	40	5	13	0	**Positive**

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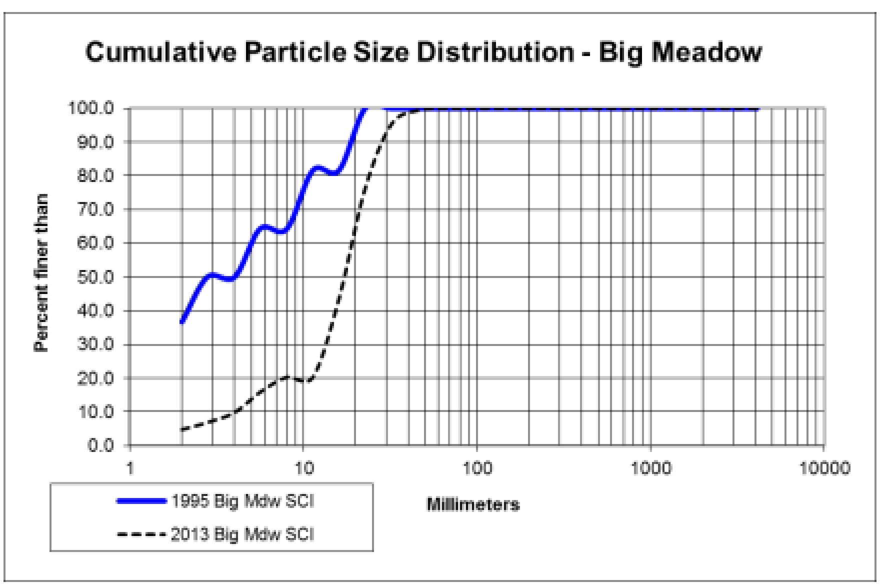

MEISS POOL DATA				
YEAR	**1995**	**2001**	**2013**	**ATTRIBUTE TREND**
# of pools	18	27	28	**Positive**
Pool riffle ratio	0.6:1	1.3:1	1.5:1	**Positive**
Median Residual Pool Depth	0.55	0.42	0.40	**Negative**
Std. Dev Residual Pool Depth	0.15	0.17	0.32	**Positive**

MEDIAN SHADE - MEISS				
YEAR	**1995**	**2001**	**2013**	**ATTRIBUTE TREND**
Median percent shade	15.5	16.5	26	**Positive**
Std. deviation shade	24.3	20.7	10.3	**Positive**

Meiss Bank Stability				
YEAR	**1995**	**2001**	**2013**	**ATTRIBUTE TREND**
# data points	**100**	**100**	**100**	-
%stable	76	74	78	**Positive**
%vulnerable	12	14	19	**Positive**
%unstable	12	8	3	**Positive**